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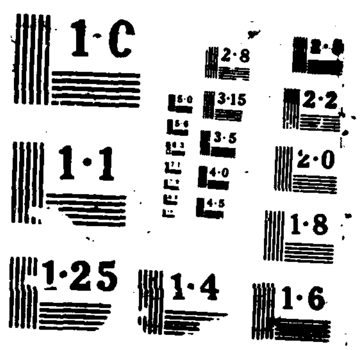
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TARGET DETECTION ROUTINE (TADER) METHODOLOGY DESCRIPTION

SEPTEMBER 1987

PREPARED BY
FORCE SYSTEMS DIRECTORATE

US ARMY CONCEPTS ANALYSIS AGENCY
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Documentation was prepared for the Target Detection Routine (TADER) developed at the US Army Concepts Analysis Agency. TADER was designed to compute the probability of operational target acquisition (POTA) of generic military units scanned by opposing sensor arrays over a fixed search period. Computed POTA vaues are input to a CAA nuclear fire planning model (NUFAM). TADER is deterministic model which employs an input target lucrativeness threshold to filter out detections not suitable for targeting. The TADER Methodology Description is structured to provide a user with detailed information on TADER model logic. Additional information on TADER model operation may be found in the TADER User's Guide (CAA-D-87-8), published separately.

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TECHNICAL PAPER
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TARGET DETECTION ROUTINE (TADER)

METHODOLOGY DESCRIPTION

September 1987

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This methodology description presents the analytic logic of the Target Detection Routine (TADER), developed during the Target Acquisition Study (TAS III), to compute values of probability of operational target acquisition (POTA) for input to a CAA nuclear fire planning model (NUFAM). Additional documentation on model operation and use is in the separately published TADER User's Guide (CAA-D-87-8). The final study report on TAS III is separately published as CAA-SR-87-23.

TARGET DETECTION ROUTINE (TADER) METHODOLOGY DESCRIPTION	SUMMARY CAA-TP-87-9

THE REASON FOR PERFORMING THIS WORK is that the methodology employed by the CAA Target Acquisition Study II (TAS II) for computing probability of operational target acquisition (POTA) was no longer operational at CAA and required update and revision. Revision consisted of construction of a new methodology, the Target Detection Routine (TADER), which computes detection susceptibility (POTA) of generic military units scanned by opposing sensor arrays over a fixed scan period. This report describes the TADER methodology.

THE PRINCIPAL FINDINGS of the work reported in this paper are:

(1) The TADER methodology uses an extension of the concept of POTA from TAS II, as well as much of the input data of that study; however, TADER is a new methodology which significantly extends the methodology of TAS II.

(2) TADER treats the following generic sensor coverage pattern types: a "fan" (typical of STANO radars and ground observers), a rectangular swath across the entire scanned sector (typical of standoff sensors traversing the sector front), and a set of coverage rectangles within the scanned sector (typical of penetrating sensors, e.g., patrol, RPV, reconnaissance air mission).

(3) TADER is a deterministic model which employs a graphical search technique to determine detectability and sensor coverage at many points and subsequently averages them over a scanned region. This technique allows more flexible sensor placement and pattern representation than did TAS II.

(4) TADER employs input target lucrativeness thresholds to screen detections on the basis of a minimum number of detected target elements required for consideration. A TADER POTA is a probability of detection at (or above) the specified lucrativeness level. TAS II did not employ a lucrativeness threshold.

THE MAIN ASSUMPTIONS are that the probabilities of detection of different targets by different systems are assumed to be statistically independent and that all detections are for a fixed "snapshot" scanning period.

THE PRINCIPAL LIMITATION is that detection of electronic emitters (SIGINT) is not modeled.

THE SCOPE OF THE STUDY addresses the assessment of average detection susceptibility, over a scanned region, of a generic military unit scanned during a fixed time period by specified sensor arrays in a specific scenario. The method is based on the POTA concept and input data types employed in TAS II.

THE STUDY OBJECTIVES were:

(1) To revise the methodology developed in TAS II for computing POTA for military units so that updated scenarios and inputs can be processed.

(2) To document and demonstrate the revised POTA methodology.

THE BASIC APPROACH was:

(1) To assess the limitations of the TAS II POTA methodology.

(2) To select features and capabilities for incorporation into a revised POTA methodology.

(3) To develop a revised POTA methodology, denoted as the Target Detection Routine (TADER), incorporating the selected capabilities.

(4) To report on the nature of the TADER methodology through exposition and illustrative examples.

THE STUDY SPONSOR is the Deputy Chief of Staff for Operations and Plans, Headquarters, Department of the Army.

THE STUDY EFFORT was conducted by Mr. Walter J. Bauman, Force Systems Directorate, US Army Concepts Analysis Agency.

COMMENTS AND QUESTIONS may be addressed to the Director, US Army Concepts Analysis Agency, ATTN: CSCA-FSC, 8120 Woodmont Avenue, Bethesda, MD 20814-2797.

Tear-out copies of this synopsis are at back cover.

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TARGET DETECTION ROUTINE (TADER) METHODOLOGY DESCRIPTION

Section I. INTRODUCTION AND BACKGROUND

1. INTRODUCTION

a. The methodologies used by the US Army Concepts Analysis Agency (CAA) for computing tactical nuclear requirements must address the allocation of weapons to potential targets and the assessment of effects of these allocations. Any selection/allocation algorithm for targets must treat the detectability of targets. Because of the potentially large number of sensors and targets in a battlefield environment and the complexity of factors affecting detectability, the target detection and acquisition process is not simulated in detail within a computerized nuclear fire planning and assessment model. Instead, targets in a nuclear fire model are characterized by probabilistic detectability factors from tables generated offline by a detailed target acquisition methodology. The offline methodology evaluates target detectability over a wide variety of scenario conditions. The resulting catalog of detectability factors, by type unit and zone, is then used as lookup tables by the nuclear fire model.

b. The offline methodologies used in the above process at CAA have been developed in three CAA studies: Target Acquisition Study (TAS),[1] performed in 1976, Target Acquisition Study II (TAS II),[2] performed in 1979, and the current study, Target Acquisition Study III (TAS III). The detectability factors calculated in each of these studies are denoted as probabilities of operational target acquisition (POTA). Although the concept of a POTA is used in the same way in all of the above studies, each one developed its own method for calculating it.

c. The methodology developed in TAS III is the Target Detection Routine (TADER) and is documented in this report and in a separate user's guide.[3] Certain TADER methodology refinements and additions designed late in TAS III are not documented herein in order to permit consistency of the documented methodology with the last complete set of POTA results. The TAS III Study Report[4] alludes to them, and TAS IV will document and report on them in detail.

d. A POTA value is always scenario dependent since it is computed for a fixed configuration of deployed sensors (numbers, types, and locations) and for a fixed set of sensor, target, and environmental characteristics. Applicability of a POTA value is restricted to the set of conditions used to generate it.

2. BACKGROUND - PREVIOUS STUDIES

a. Prior to January 1976, percent of knowledge (POK) estimates were used by CAA as the basis for simulating target acquisition in tactical nuclear force (TNF) studies. These values were determined subjectively, taking into consideration all known sources of target acquisition projected through the

1980 timeframe. Percent of knowledge was defined as the probability that a given unit type at a specified distance from the forward line of own troops (FLOT) would be acquired by the opposing force.

b. In May 1976, the Target Acquisition Study (TAS) was completed by CAA. This study developed the POTA concept as a replacement for the POK concept. As defined in the original TAS, POTA was the probability of detecting, identifying, and locating various types of potential targets at prescribed distances from the FLOT during a random, but limited, period of time in a day of intense combat. The Nuclear Requirements Methodology II (NUREM II) Study,[5] completed in January 1978, and the Theater Nuclear Force Requirements - 1984 (NUREQ-84) Study,[6] completed in January 1979, were studies which utilized the POTA concept.

c. Following publication of the NUREQ-84 Study Report, a decision was made to review and update the POTA methodology and data base as a major quality assurance (QA) effort, in preparation for the next major nuclear study. As a result, TAS II was performed and was completed in August 1979. The POTAs calculated by that study were the standard until 1985, when CAA, in TAS III, undertook to update the TAS II POTAs and methodology to support current nuclear force requirement studies. POTA still means the same it did in TAS II, except that now target recognition has replaced target identification in the definition.

3. TARGET ACQUISITION STUDY III (TAS III)

a. TAS III was structured in two phases. In the first phase, the primary objectives were:

(1) To restore operational capability of the computerized TAS II methodology. That methodology had not been exercised for 5 years. Archived computer files had to be restored, verified and tested.

(2) To update inputs used in TAS II to include sensors, targets, environments, and scenarios applicable to current nuclear requirement studies at CAA. The POTAs generated by TAS II were being widely applied to cases and conditions beyond the scope of that study. An update of TAS II, to include more cases and conditions, appeared necessary.

(3) To determine new POTA values for use in the Nuclear Requirements Study - 1992 (NUREQ-92) at CAA. NUREQ-92 addressed scenarios for which TAS II POTAs are inappropriate. New POTAs for new scenario conditions had to be generated.

b. In the second phase of TAS III, the restored POTA methodology from TAS II was to be enhanced to include battalion-size units, units in assembly areas and on the move, and other targets not addressed by TAS II but needed for NUREQ-92.

4. TARGET DETECTION ROUTINE (TADER) DEVELOPMENT

a. The archived computer files from the TAS II project could not be reconstructed in a complete and consistent manner, even with the documentation from the TAS II Study Report. Examination of the TAS II model, Probability of Operational Target Acquisition Routine (POTAR), revealed several deficiencies including:

(1) Sensor placement rules did not permit individual location of emplaced sensors, but restricted them to uniform distribution along a straight line.

(2) The coverage of penetrating sensors did not allow for flight paths of more than one leg in a single direction.

(3) Lucrativeness thresholds for determining when the number of detections was sufficient for target recognition (confirmation of the presence of an expected target type) were not addressed.

(4) Artillery/mortar firing and activity/environment (movement/concealment) factors were not properly accounted for or treated.

b. After extensive investigation, a new, as opposed to restored, methodology was determined to be necessary. The TAS III POTA model, denoted earlier as the Target Detection Routine (TADER):

(1) Is a fully computerized, deterministic model, written in FORTRAN and treating expected values.

(2) Retains the basic definition of the POTA concept from TAS II, but with an emphasis on target recognition rather than identification (knowing the name of the unit found).

(3) Uses most of the inputs of TAS II. Moreover, TADER's additional capabilities allow conditions not treated by TAS II, such as target unit posture, to be addressed.

(4) Allows POTAs to be calculated over a broader range of scenarios than TAS II.

(5) Screens unit detections on the basis of sufficiency for target recognition (lucrativeness).

(6) Eliminates sensor placement and coverage restrictions of POTAR.

(7) Properly accounts for artillery/mortar firing and activity/environment factors.

Section II. CONCEPT OVERVIEW

5. SCOPE

a. **General.** The principal purpose of TAS III was to develop a methodology for determining the probability of detection of combat units of various types at different distances from the FLOT. The values developed are called 'POTA' (probability of operational target acquisition) or 'unit POTA' values (see Figure 1). The target units typically are of company, battalion, command post, and battery sizes. The POTA values are averages over zones of prespecified depth, currently 0-3, 3-12, 12-25, 25-100, and 100-300 km. The POTA values for a zone are developed by first determining the POTA values for uniform (1 km) squares in the zone, and then averaging these over the whole zone.

POTA THE PROBABILITY OF OPERATIONAL TARGET ACQUISITION IS THE PROBABILITY OF DETECTING, RECOGNIZING, AND LOCATING VARIOUS TYPES OF POTENTIAL TARGETS AT PRESCRIBED DISTANCES FROM THE FLOT DURING A RANDOM BUT LIMITED PERIOD OF TIME IN A DAY OF INTENSE COMBAT.

Figure 1. POTA Concept Definition

b. **Assumptions.** In order to derive POTA values, assumptions must be made concerning knowledge of the targets. Specifically, target classification (e.g., battalion/battery/command post types), composition (table of organization and equipment (TOE) in terms of people, wheeled vehicles, tracked vehicles, artillery tubes (or rocket launchers), and mortar tubes), and approximate location must be known. Target units must not overlap each other. Their classification and approximate location are provided by signals intelligence (SIGINT) sensors and other IPB (intelligence preparation of the battlefield) techniques. The TOE of the units is general knowledge.

c. **Restrictions**

(1) The TAS III methodology treats only target signatures susceptible to visual, acoustic, or radar scanning. SIGINT could be included, however, if appropriate data was available. The method treats individual detection of target elements as statisticlly independent. The independence assumption enables a compact, relatively fast analytic solution.

(2) A POTA is computed for a specific force of emplaced and moving sensors scanning specified target zones. Locations of sensors are specified by user input, and sensor coverage patterns are represented in "cookie-cutter" fashion. It is possible to modify the TADER methodology to compute POTAs for a unit at a specified location, but such modification was not considered within the scope of TAS III. Capabilities and characteristics of sensors are fixed (by input) and are constant throughout the timeframe represented. That timeframe is essentially a "snapshot." Target environments and states are represented in terms of average (expected value) frequency, specified by the user.

(3) The POTA values do not provide a target unit list or target value ranking. A POTA for a unit type only provides data on the overall susceptibility of that unit type to detection by a specific array of sensors in a specific scenario. A POTA does not treat the importance of element types within a unit. The detection of a truck has the same weight as the detection of a tank in the final POTA calculation. Also, time perishability of detection information is not directly treated.

6. POTA CALCULATION OVERVIEW (TOP DOWN). The end product of TADER is the unit POTA for a target unit randomly located in a target zone and searched for by all scenario systems. The formulas and inputs necesary to arrive at this zone unit POTA are determined in the following manner (parameter names are not necessarily the same as those used later in the appendix in the general case expositions and examples. Their designation here is solely to illustrate the overall model logic):

a. The unit POTA for (a random location in) the target zone is computed as the arithmetic average of the combined unit POTAs computed for each grid square of the target zone.

POTA = unit POTA in target zone z

$$= \left(\sum_{g=1}^{nz} POTA_g \right) / nz$$

where

nz = number of grid squares in target zone z.

b. The combined unit POTA for a grid square g is computed by combining the noncounterfire and counterfire POTAs for the unit.

$POTA_g$ = probability at least one system detects the target unit in g as lucrative

$$= 1. - (1. - POT1_g) x (1. - POT2_g))$$

where

$POT1_g$ = probability at least one noncounterfire system of nn systems detects the unit in g as lucrative

$POT2g$ = probability at least one counterfire system of nc systems detects the unit in g as lucrative

c. A noncounterfire POTA for all nn noncounterfire systems versus the unit in grid square g is computed as:

$POT1_g$ = probability at least one noncounterfire system of nn systems detects the unit in g as lucrative

$$= 1. - \prod_{s=1}^{nn} (1. - POT_{sg})$$

where

POT_{sg} = probability system s detects the unit in g as lucrative

d. A counterfire POTA is computed for all nc counterfire systems versus the unit in g as:

$POT2g$ = probability at least one counterfire system of nc systems detects the unit in g as lucrative

$$= \left[1. - \prod_{s=1}^{nc} (1. - POV_{sg}) \right] x PFIR$$

where

POV_{sg} = probability counterfire system s detects the unit as lucrative, given that the unit is firing

PFIR = probability the target unit is firing

e. For a noncounterfire system s versus a target unit in grid square g,

POT_{sg} = probability system s detects the unit in g as lucrative

$$= 1. - \prod_{i=1}^{M} (1. - PU_{isg})$$

where

M = number of sensors in system s

PU_{isg} = probability the single sensor, i, detects the target unit as lucrative

f. For a counterfire system s versus a firing unit in grid square g,

POV_{sg} = probability system s detects the unit as lucrative

$$= 1. - \prod_{i=1}^{M} (1. - PO_{isg})$$

where

M = number of sensors in system s

PO_{isg} = probability the sensor i (of system s) detects enough volleys (of the unit in g) to be "OR" lucrative

= the probability of at least TO_v detections in a binomial distribution of volleys with single detection probability = P_{isvg}

where

TO_v = "OR" lucrativeness threshold for volleys

P_{isvg} = the weighted operational probability, given coverage, that a single sensor (of the specified system s) detects a single volley of the target unit in g.

g. For each emplaced sensor i of a noncounterfire system s scanning a grid square g:

PU_{sig} = probability the single sensor, i, detects the target unit as lucrative.

$$= PA_s \, x \left(1 - \prod_{j=1}^{5} (1 - PO_{isjg}) + A \right)$$

where

PO_{isjg} = probability the sensor i (of system s) detects enough element j (of the unit in g) to be "OR" lucrative

= the probability of at least TO_j detections in a binomial distribution of N_j elements with single detection probability = p_{isjg}, where TO_j is the "OR" lucrativeness threshold for element type j and N_j is the number of element type j in the unit.

PA_s = availability/survivability factor for system s

and

A = a term accounting for effects of "AND" lucrativeness

pisjg = weighted operational probability, given coverage that a single sensor (of system s) detects a single target element (of specified type j) of the target unit in g.

h. The pisjg definition depends on whether system s is a noncounterfire or a counterfire system. For each sensor of each system, pisjg is a single sensor/single element operational detection probability whose computation is based on the target unit being in that grid square and scanned by that sensor. The various sensor degradation factors, the sensor capability activity/environment factors, and the inherent detection probability are combined to form an operational probability of detection, given coverage, of a single target element by a single available sensor for each activity/environment condition. This is then weighted by the activity/environment frequencies for element types in the target unit to yield pisjg.

(1) Noncounterfire System. For each emplaced sensor i of a noncounterfire system s scanning a single target element of type j in a specific grid square, g:

$$p_{isjg} = \sum_{e=1}^{4} FACT_{ej} \, x \, PDET_{isjg} \, x \, DEG_{sje}$$

where

$FACT_{ej}$ = frequency of element type j in activity/environment e

$PDET_{isjg}$ = input inherent detection probability for the single sensor, i, of system s against a single element of type j located in grid square g

DEG_{sje} = product of the sensor degradation factors (excluding availability/survivability) for element type j in activity/environment e.

(2) **Counterfire System.** For each emplaced sensor i of counterfire system s scanning a grid square g,

$$p_{isjg} = PA_s \, x \, PVOL_{isjg}$$

where

PA_s = availability/survivability for system s

$PVOL_{isjg}$ = operational probability that at least one round of an in-range volley fired by element type j in a grid square g is detected by the single sensor, i, of system s. This includes weighting for sensor degradation factors, but excludes activity/environment degradation factors.

7. **INPUT OVERVIEW.** The input data required by TADER is summarized in Figure 2 and explained in more detail thereafter.

- SENSOR CHARACTERISTICS (IN SURVEILLANCE ZONES)
  - INHERENT DETECTION PROBABILITY ACCORDING TO RANGE OF TARGET ELEMENT
  - CAPABILITY MODIFIERS BY TARGET ENVIRONMENT AND ACTIVITY
  - DEGRADATION FACTORS (AVAILABILITY, SURVIVABILITY, WEATHER, WIND, LOS, SMOKE)
  - LOCATIONS
  - COVERAGE PATTERNS
- TARGET CHARACTERISTICS (BY TARGET ZONE)
  - UNIT STRUCTURE (TOE FOR EACH TARGET ELEMENT TYPE)
  - ENVIRONMENT
  - ACTIVITY
  - ARTY/ROCKET/MORTAR FIRING PARAMETERS
- LUCRATIVENESS THRESHOLDS
  - MINIMUM DETECTED SIZE NEEDED TO MERIT TARGETING

Figure 2. Input Overview

a. Sensor Characteristics

(1) **Sensor System.** A sensor system is a "suite" of sensors of a common type, i.e., each sensor of the system has exactly the same characteristics except for emplacement location.

(2) **Sensor Types.** TADER treats the following sensor types:

(a) STANO radars.

(b) Forward observers.

(c) Counterbattery radars.

(d) Standoff side-looking airborne radar (SLAR).

(e) Penetrating aircraft.

(f) Remotely piloted vehicles (RPVs).

(g) Patrols.

(h) Emplaced counterbattery acoustic sensors (REMBASS).

(3) **Sensor Zone.** Most sensor characteristics are input as a function of distance interval relative to the sensor location, denoted as a sensor zone. A sensor zone, relative to a sensor location, is the region between two specified distances from the emplaced sensor or sensor path. A sensor characteristic for a sensor zone is based on an average value over all sensor-target distances in that zone. The entire range of coverage for a sensor is partitioned into sensor zones. TADER allows up to 10 sensor zones to be defined.

(4) **Inherent Detection Probability.** Inherent detection probability is the probability that a single target element of specified type, located in a specified sensor zone, is detected by a single sensor of specified type under ideal operational conditions (i.e., test conditions). Detection is normally a function of target distance from sensor. In TADER, it is a function of sensor zone, which is a distance interval relative to a sensor.

(5) **Degradation Factors (all sensors).** A decimal factor by which inherent detection probability is multiplied in order to reduce sensor effectiveness due to different conditions. If a condition is known to adversely affect sensor performance, the sensor's residual effectiveness relative to its maximum effectiveness is the degradation factor. Except where noted below, degradation factors are assumed to be the same in all target zones. The specific factors are:

(a) Relative effectiveness due to weather degradation.

(b) Relative effectiveness due to wind degradation.

(c) Relative effectiveness due to smoke or dust degradation.

(d) Relative effectiveness due to crew performance problems (varies inversely as the degree of crew involvement, i.e., increased automation means less crew involvement and higher relative effectiveness).

(e) Relative effectiveness due to line of sight restrictions, i.e., probability sensor will have a view of target in target zone unobstructed by terrain (vegetation is accounted for in activity/environment factors, described later for both targets and sensors).

(f) Relative effectiveness due to visibility restrictions, i.e., probability that target contrast in target zone will not be reduced to less than 2 percent by atmospheric effects, such as fog or haze.

(g) Availability (fraction available): fraction of time a sensor actually operates or functions (takes into account movement from one operating location to another, maintenance down time, duty cycle, etc.).

(h) Survivability: fraction of sensors still alive when performance is required. Usually, this is the average number alive during the 2-hour search period divided by the number alive at the beginning of the period. Intense combat is assumed to begin with the search period.

(6) A/E Degradation Factors (all sensors). Four additional factors by which inherent detection probability is degraded (after application of above factors) to account for effects of each of the four activity/environment (A/E) states of the elements: moving/in the open, moving/in woods or towns, stationary/in the open, and stationary/in woods or towns.

(7) Locations. A specific location for each emplaced sensor may be determined by the user. For penetrating aircraft or standoff SLAR systems, a mission flight path is defined. A user may also specify a standoff distance, along which sensors are uniformly emplaced.

(8) Coverage Pattern. TADER treats the coverage pattern of a sensor as a user-defined area with a specific shape. The allowable shapes and defining parameters for various types of sensors are illustrated in Figure 3 and are as follows:

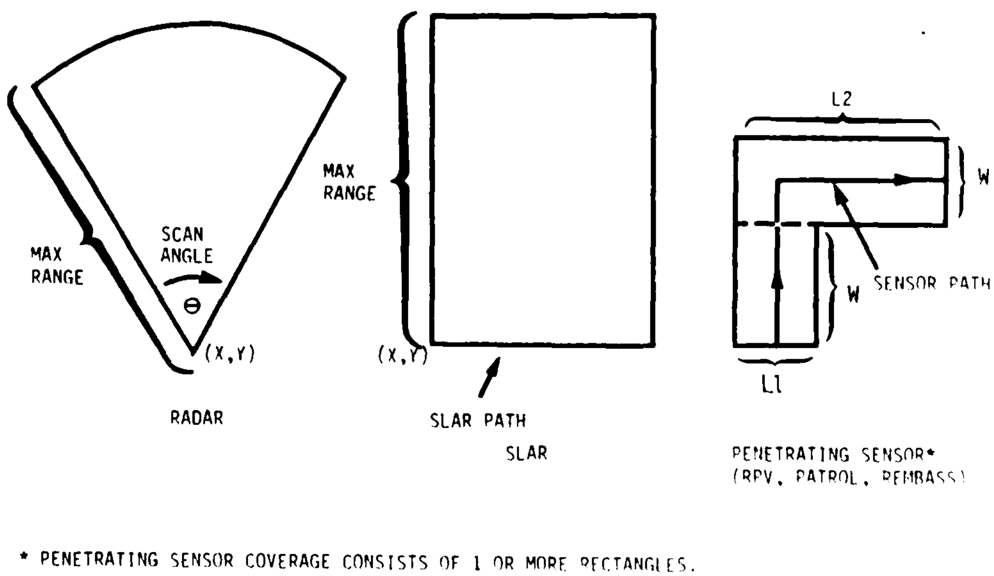


Figure 3. Sensor Pattern Types

(a) **STANO Radar.** The allowable shape is a pie wedge representing the area covered by a radar scanning back and forth through a specified scan angle. The maximum range and the scan angle determine the coverage pattern. The sensor location determines the location of the wedge. The center axis of radar scan (and its pattern) is always modeled as perpendicular to the FLOT. This type of coverage pattern also characterizes ground-based forward observers.

(b) **SLAR (standoff).** The standoff SLAR is treated as traversing the entire width of the sector. Its coverage pattern is a rectangle with width, parallel to the FLOT, equal to the sector width, and with length, perpendicular to the FLOT, equal to the maximum range of the sensor.

(c) **Penetrating Sensor.** Penetrating sensors include RPVs and patrols (short-range and long-range) as well as overflying aircraft and strings of emplaced sensors (e.g., REMBASS). TADER represents coverage for a system of penetrating sensors as a set of rectangles with user-specified length, width, and location within a sector. All rectangle widths are parallel to the FLOT and all lengths are perpendicular to it. As shown in Figure 3, the path of a penetrating sensor is associated with its rectangular sections.

b. Target Characteristics

(1) **Target Zones.** The battlefield sector is partitioned into rectangular target zones. Most target characteristics are input as a function of target zone. A target zone is a rectangular strip with the same width as the sector of interest and, in depth, including territory between two specified distances beyond the FLOT. An example with five target zones is shown in Figure 4. TADER can treat up to 10 target zones. For each target unit type, a POTA is computed for each target zone. The unit POTA for a zone assumes that the units have a uniform random distribution over the area of the zone. The target zones are numbered in order of distance from the FLOT and must be continuous and covering the entire sector.

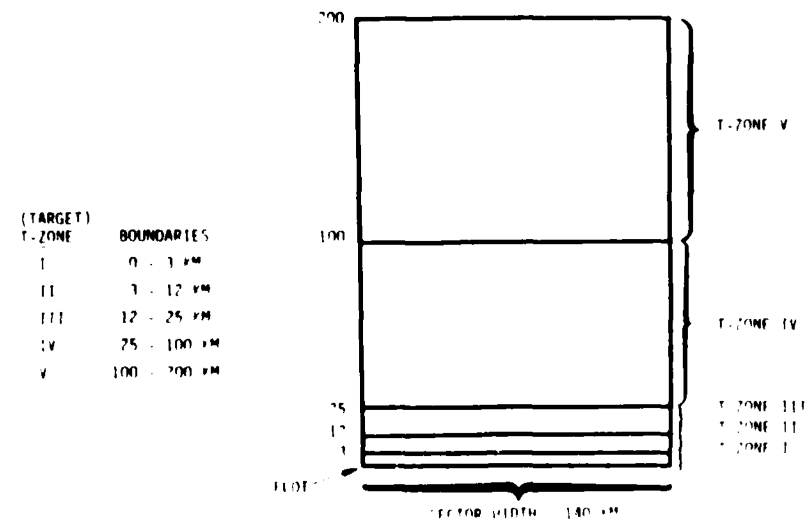


Figure 4. Example Target Zones

(2) **Unit Structure**

(a) General. Targets in TADER are model representations of military units (e.g., maneuver battalions). They consist of target elements, e.g., single weapons carriers, or fired volleys, individually susceptible to detection. TADER can process up to five element types for any sensor system. The TADER user inputs the number of each element type normally found in the unit in each target zone. This can reflect a unit being at different strengths in different echelons. A user can input a strength level commensurate with elements surviving at the time of the search to reflect attrition prior to (but not during) the search period simulated. Also, all elements of a target unit are modeled as essentially concentrated at a point, i.e., unit area is not considered. The POTA for a unit is the combination of the separate probabilities of noncounterfire and counterfire sensor systems finding that unit.

(b) Targets of Noncounterfire Sensor Systems. The number of target elements in a unit and zone is treated as constant for the duration of the sensor search period. There is no provision for attrition in the process. The five element types subject to detection by noncounterfire systems are:

1. Personnel.

2. Wheeled vehicles.

3. Tracked vehicles.

4. Artillery/rockets (tubes/launchers).

5. Mortars (tubes).

(c) Targets of Counterfire Sensor Systems. Counterfire sensor systems detect units firing artillery, rockets, or mortars in accordance with the number of volleys fired by the units during the search period and the number of rounds fired per volley. Volleys, therefore, are the element type subject to detection by counterfire systems. In a target unit, either all launchers are treated as firing or none are treated as firing. The likelihood of a unit type firing is input in terms of the fraction of all deployed units of a specified type which are firing during the search period. This fraction is a ceiling on the unit POTA generated by counterfire systems since such systems cannot detect a nonfiring unit.

(3) Activity/Environment Factor. The detectability of a target unit depends, among other factors, on its activity (moving or not moving) and its environment (in the open or in woods or towns). TADER, therefore, defines four target activity/environment states, which are assumed to be all-inclusive. These are:

(a) Moving in the open.

(b) Moving in woods or towns.

(c) Stationary in the open.

(d) Stationary in woods or towns.

For each target unit in each target zone, the user inputs the frequency (fraction of time) each element type is expected to be in each of the above four activity/environment states.

(4) Target Lucrativeness. The simplest and most basic criterion for detection of a unit is to treat the unit as detected if at least one target element in it is detected. However, such a criterion is often not practical because it can give excessive weight to small (in numbers) detections with an associated risk of accepting, as a valid target, a detected unit too small to justify the resources required to destroy it. Therefore, the TADER POTA method allows the user to specify a threshold of detections which is used to "filter out" detections at subthreshold level. The term used to describe filtered-out detections is "nonlucrative" and is equivalent to having insufficient evidence that a unit of a given type has been spotted, classified, and placed at a given location. There are two types of lucrativeness thresholds, denoted by "OR" and "AND," that can be specified. Detections are "OR" lucrative if at least the "OR" level is detected for at least one element type. Detections are "AND" lucrative if at least the "AND" level is detected for all applicable element types. A unit POTA is the probability of detections being lucrative under either the "OR" or the "AND" lucrativeness. For each target unit, TADER requires assignment of an "OR" lucrativeness threshold for each element type. In addition, an "AND" lucrativeness threshold can be specified for wheeled vehicles and for tracked vehicles. A threshold is in terms of the minimum fraction of elements (of each type) that must be detected. The model converts the fraction to a threshold level by applying it to the input TOE.

c. **Grid Square Input.** TADER calculates a unit POTA for a target unit located at a specific point location in a target zone. It then averages the "point" unit POTAs over all "points" in a zone to determine a unit POTA for the (unit randomly located in the) target zone. The points (at which unit POTAs are calculated) are determined as the centers of squares in a grid of squares specified by input for each target zone; i.e., each target zone is partitioned into a grid of uniform squares of specified side dimension (in km).

8. COMPUTATIONAL SEQUENCE

a. The actual sequence of computations for determining the zone unit POTA is summarized below.

(1) The target zone is partitioned into grid squares of uniform (input-specified) size.

(2) For each deployed sensor of each system, a single-sensor unit POTA for each grid square is computed, based on the target unit being in that grid square and scanned by that sensor. This is the probability that the sensor detects the target unit as lucrative.

(3) For each system, a single-system POTA for each grid square is computed by combining single-sensor POTAs. This is the probability that the system detects the target as lucrative.

(4) Over all noncounterfire systems, the noncounterfire unit POTA for each grid square is computed by combining single-system POTAs versus the unit. This is the probability that at least one noncounterfire system detects the unit as lucrative.

(5) Over all counterfire systems, the counterfire unit POTA for each grid square for each unit capable of firing artillery/or mortars (element type J = 4 or 5) in the grid square is computed by combining single-system POTAs versus the unit. This is the probability that at least one counterfire system detects the unit as lucrative.

(6) The combined unit POTA for each grid square is computed by combining the noncounterfire and counterfire unit POTAs in each square. This is the probability that at least one system detects the target unit as lucrative.

(7) The unit POTA for the target zone is computed by averaging the grid square unit POTAs over all grid squares in the target zone. Averaging randomizes the effects of target location over the target zone.

b. Appendix A to this paper depicts the above methodology in more detail via a series of expositions and examples in scripted briefing format. The expositions consist of the methodology of the general case in terms of definitions and formulas for calculation of a POTA. Interleaved within the expositions are example applications with displayed calculations to illustrate sections of exposition. The use of concurrently explained examples serves to fix the concepts for the reader.

APPENDIX A

TADER METHODOLOGY EXPOSITION AND EXAMPLE

This appendix presents a detailed exposition of the TADER methodology by laying out the model inputs and general case expressions for *noncounterfire* and counterfire detection, interleaved with the appropriate elements of an illustrative example, and concluding with the tying together of the component parts into a final POTA value for the hypothetical target. The input values for this example are of reasonable magnitude but fictitious, in that they are not the values for any real sensor system or target.

(NOT USED)

Section I. EXAMPLE CASE

EXAMPLE CASE

- THE EXAMPLE CASE CONSISTS OF:
  - TWO SLAR MISSIONS VS A STYLIZED ENEMY UNIT
  - THE ENEMY UNIT CONSISTS OF 800 PERSONNEL, 10 WHEELED VEHICLES (TRUCKS), AND 20 TRACKED VEHICLES
  - THE ENEMY UNIT IS RANDOMLY LOCATED IN A TARGET ZONE BETWEEN 25 KM and 100 KM BEYOND THE FLOT
  - THE SLAR MISSION IS PARALLEL TO THE FLOT AT A STANDOFF OF 25 KM AND WITH A SCAN RANGE OF 100 KM
  - A UNIT DETECTION IS DEEMED LUCRATIVE IF EITHER

    2 TRUCK DETECTIONS OR 4 TRACKED VEHICLE DETECTIONS ARE REGISTERED

    OR

    1 TRUCK DETECTION AND 2 TRACKED VEHICLE DETECTIONS ARE REGISTERED

A1

EXAMPLE CASE

The basic description of the example case is as indicated in the chart. While the example is very limited in scope, it will serve to illustrate concepts without unwieldy computations. A more general example would employ a force of more than one sensor type and would compute POTAs for all target zones in the sector of interest. While the presence of personnel in the unit is noted, personnel generally are not a factor in POTA determinations unless very low lucrativeness thresholds (e.g., 10 percent), unacceptable in cases to date, are used.

(NOT USED)

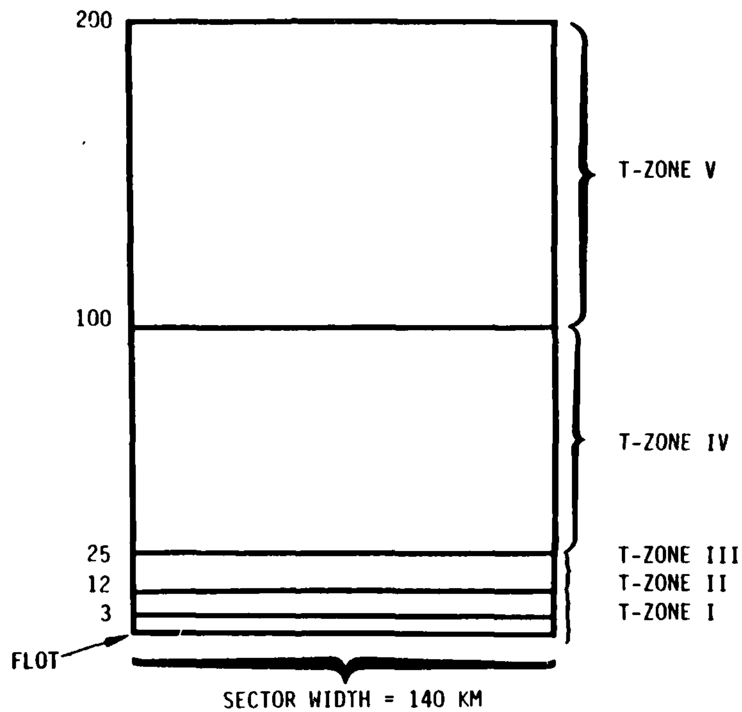
Section II. TARGET ZONES/SENSOR ZONES

US ARMY

CONCEPTS ANALYSIS AGENCY

TARGET ZONES (EXAMPLE DATA)

(TARGET) T-ZONE	BOUNDARIES
I	0 - 3 KM
II	3 - 12 KM
III	12 - 25 KM
IV	25 - 100 KM
V	100 - 200 KM



A2

TARGET ZONES (EXAMPLE DATA)

The region available for scanning is rectangular in shape and is denoted as a sector. In the chart the FLOT is the lower boundary of the sector. The sector is partitioned by user input into rectangular target zones, also denoted as T-zones in the chart. TADER can treat up to 10 target zones. For each target unit type, a POTA is computed for each target zone. The unit POTA for a zone assumes that the location of the unit has a uniform random distribution over the area of the zone. The target zones are numbered in order of distance from the FLOT and must be continuous and covering the entire sector. The width of each target zone is the same as the width of the sector.

For the example case, a sector of width 140 km and depth 200 km is partitioned into five target zones of the sizes shown. These five zones were the same ones used in TAS II. However, their sizes are user-specified and, therefore, flexible.

SENSOR ZONES (EXAMPLE DATA)

(SENSOR) S-ZONE	DISTANCE FROM SENSOR
I	0-3 KM
II	3-12 KM
III	12-25 KM
IV	25-100 KM
V	100-225 KM

NOTE: THE SAME S-ZONES ARE APPLICABLE TO ALL STANDOFF TYPES OF SENSOR SYSTEMS

A3

SENSOR ZONES (EXAMPLE DATA)

Sensor capability (detection probability) with respect to a target depends on how far away that target is from the sensor. While an ideal methodology would vary sensor capability continuously with distance to the target, the TAS III study data and methodology are based on standoff sensor capability being aggregated into discrete range intervals, denoted here as "sensor zones," relative to the sensor location. Thus, instead of detection probability being a continuous function of distance from target, in TADER it is a function of the sensor zone which contains the target unit.

Strictly speaking, the sensor zone is a distance interval on a radial line emanating from a sensor. In the TADER methodology, up to 10 sensor zones can be defined, in terms of distance interval, on a line from an emplaced sensor. The zones are numbered in order of distance from the sensor. For a scenario, only one set of sensor zones is defined and is applicable to all standoff (nonpenetrating) sensor types in that scenario. Detection probability of a penetrating sensor against a target unit is treated as a function of the target zone containing the target unit, i.e., it is based on distance from the FLOT rather than distance from the sensor.

For the example case, five sensor zones are defined. The last (furthest from sensor) zone has effectiveness measurements extending beyond 200 km distance, because, for a sensor emplaced at a standoff, the distance to the target is the sum of the standoff (25 km in example) and the distance of the target beyond the FLOT (up to 200 km).

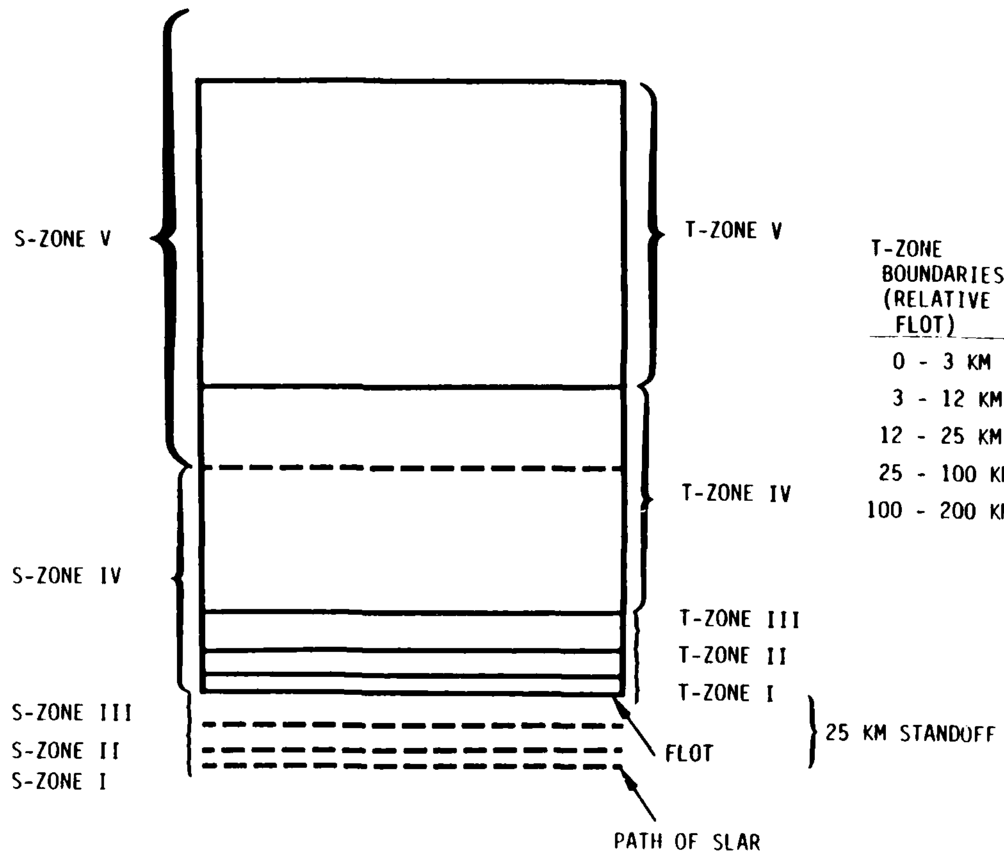
US ARMY

CONCEPTS ANALYSIS AGENCY

EXAMPLE - SENSOR AND TARGET ZONES

S-ZONE BOUNDARIES (RELATIVE TO SENSOR)

0 - 3 KM
3 - 12 KM
12 - 25 KM
25 - 100 KM
100 - 225 KM



T-ZONE BOUNDARIES (RELATIVE TO FLOT)

0 - 3 KM
3 - 12 KM
12 - 25 KM
25 - 100 KM
100 - 200 KM

A4

EXAMPLE - SENSOR AND TARGET ZONES

In the example, both sensor and target zones are defined in terms of similar distance intervals. However, a target zone is relative to the FLOT and a sensor zone is relative to the sensor location. The distance intervals defining target zones need not be the same as those defining sensor zones. In the illustration shown here, a SLAR traverses the sector at a standoff of 25 km behind the FLOT. A target in the sector is in a single target zone, but the sensor zone it is in depends on the type and location of the sensor.

(NOT USED)

Section III. TARGET UNIT CHARACTERISTICS

CONCEPTS ANALYSIS AGENCY

GENERAL CASE
TARGET UNIT STRUCTURE

- A UNIT IS A TARGET UNIT OF SOME TYPE (E.G., MANEUVER CO, DIVISION CP) AND CONSISTS OF TARGET ELEMENTS
- AN ELEMENT TYPE IS ONE OF

TYPE	DESCRIPTION
J = 1	PERSONNEL
2	WHEELED VEHICLES
3	TRACKED VEHICLES
4	ARTILLERY/ROCKETS (TUBES/LAUNCHERS IF NOT FIRING, VOLLEYS IF FIRING)
5	MORTARS (TUBES IF NOT FIRING, VOLLEYS IF FIRING)

- FOR EACH ELT TYPE J IN EACH UNIT TYPE I IN EACH TARGET ZONE K, DEFINE

PTGT(I,J,K) = NUMBER OF TARGET ELTS OF TYPE J IN UNIT I AND TARGET ZONE K

OR = NUMBER OF VOLLEYS FIRED BY ELT TYPE J=4,5 (COUNTERFIRE)

A5

GENERAL CASE - TARGET UNIT STRUCTURE

Targets in TADER are whole units or component elements. A target unit is a model representation of a military unit (e.g., a maneuver battalion). A target element is a single person, weapon, or carrier susceptible to detection. TADER can process up to five element types (though this capability can be expanded). The specified element types apply to all target units modeled. The number of each element type in a target unit should be based on the Table of Organization and Equipment (TOE) of the unit. For firing target elements of type J = 4 or 5, the volleys fired by the element type during the search period becomes the element parameter of interest. Since not all equipment types can be represented, many will have to be combined into generic families, such as "wheeled vehicles." In turn, inherent detection data based on specific targets will have to be combined, aggregated and expressed relative to an average member of an element type.

Since a POTA is calculated for each target zone, the input number of target elements in a unit may be different in different target zones. This could reflect a unit being at different strengths when deployed at different echelons. The number of target elements in a unit and zone is treated as constant for the duration of the search period. There is no provision for attrition in the process. A user can input a strength level commensurate with elements surviving at the time of the scan to reflect attrition prior to (but not during) the period simulated. Also, all elements of a target unit are modeled as essentially concentrated at a point, i.e., unit area is not considered.

Artillery, rocket, or mortar elements (types 4 and 5) are represented in two forms, as nonfiring launchers/carriers and as firers, expressed in terms of volleys fired during the search period. Counterfire sensor systems detect these element types as volleys fired.

US ARMY

CONCEPTS ANALYSIS AGENCY

TARGET STRUCTURE INPUT FOR FIRING ARTY/MORTAR

- ARTY/MORTAR FIRINGS BY ELT TYPE J=4,5 ARE EXPRESSED IN TERMS OF VOLLEYS FIRED DURING THE SEARCH PERIOD

- FOR EACH ELT TYPE J=4,5 IN UNIT I AND TARGET ZONE K, LET:
  - *PFIR(I,J,K)* = FRACTION OF *ALL DEPLOYED UNITS* OF TYPE I IN TGT ZONE K WHICH ARE FIRING DURING THE SEARCH PERIOD.
  - ISAL(I,J,K) = NR OF VOLLEYS FIRED BY A FIRER ELT DURING SEARCH PERIOD
  - IRPS(I,J) = NR OF ROUNDS FIRED PER VOLLEY BY THE FIRER ELT

A6

TARGET STRUCTURE INPUT FOR FIRING ARTY/MORTAR

Counterfire sensor systems detect only firing element types 4 and 5 and do so in terms of volleys fired. Firings are expressed in terms of the number of volleys fired by a firing element during the search period and the number of rounds fired per volley. In a target unit either all launchers are treated as firing or none are treated as firing. The likelihood of a unit type firing is input in terms of the fraction of all deployed units of a specified type which are firing during the search period. This fraction is a ceiling on the unit POTA generated by counterfire systems since such systems cannot detect a nonfiring unit.

EXAMPLE CASE
TARGET UNIT STRUCTURE

- THE SINGLE TARGET UNIT (I = 1) HAS THE FOLLOWING COMPOSITION IN ALL TARGET ZONES K

ELT TYPE	PTGT(I,J,K)
J = 1 (PERSONNEL)	800
= 2 (WHEELED VEHICLES)	10
= 3 (TRACKED VEHICLES)	20
= 4 (ARTILLERY/ROCKETS)	0
= 5 (MORTARS)	0

A7

EXAMPLE CASE - TARGET UNIT STRUCTURE

The chart shows the postulated strength levels of the five element types in the unit of the example case. Strengths are the same in all target zones (though this need not be so, if the user wishes otherwise). Only three of the five element types have nonzero representation. The numbers reflect assigned unit strength, not just the strength of elements in the open. Modifiers for environmental concealment are also input, as explained on subsequent charts.

GENERAL CASE
TARGET UNIT ACTIVITY/ENVIRONMENT FACTORS

- FOR EACH TGT ELEMENT TYPE J IN TGT UNIT TYPE I AND TARGET ZONE K
  - FACT (I,J,K,A/E) = FRACTION OF TARGET ELEMENTS IN ACTIVITY A AND ENVIRONMENT E

WHERE: A/E = TGT ACTIVITY/ENVIRONMEMT STATE
1 = MOVING/IN OPEN
2 = MOVING/NOT IN OPEN
3 = STATIC/IN OPEN
4 = STATIC/NOT IN OPEN

$$\sum_{A/E=1}^{4} \text{FACT}(I,J,K,A/E) = 1.00$$

A8

GENERAL CASE - TARGET UNIT ACTIVITY/ENVIRONMENT FACTORS

The detectability of a target unit depends on the activity (moving or not moving) and the environment (in the open or not in open) of the target elements comprising that target. This chart defines the frequency of each target/element activity/environment state. In addition to target element type (J), the frequency can depend on the target unit type (I) and the target zone (K). Since the defined activity and environment states are assumed to represent all cases, the summed activity/environment frequencies for a single combination of target element type, target unit type and target zone must be unity. The model is limited to four activity/environment states.

CONCEPTS ANALYSIS AGENCY

EXAMPLE CASE
TARGET UNIT ACTIVITY/ENVIRONMENT FACTORS

- FOR ELEMENTS OF UNIT I IN TARGET ZONE K=4
  - ACTIVITY/ENVIRONMENT FACTORS (FACT(I,J,K,A/E)) ARE

	ELEMENT TYPE (J)				
ACTIVITY/ENVIRONMENT	J=1	2	3	4	5
A/E=1 (MOVING/OPEN)	.05	.05	.05	.05	.05
A/E=2 (MOVING/NOT OPEN)	.05	.05	.05	.05	.05
A/E=3 (STATIC/OPEN)	.10	.10	.10	.10	.10
A/E=4 (STATIC/NOT OPEN)	.80	.80	.80	.80	.80

A9

EXAMPLE CASE - TARGET UNIT ACTIVITY/ENVIRONMENT FACTORS

This chart defines the activity and environment factors for the example case. The illustrated factors are only for target zone IV. Factors must be defined for all activity/environment states in all combinations of target unit type, target element type and target zone. Note that the state frequencies sum to 1.00 for each element type.

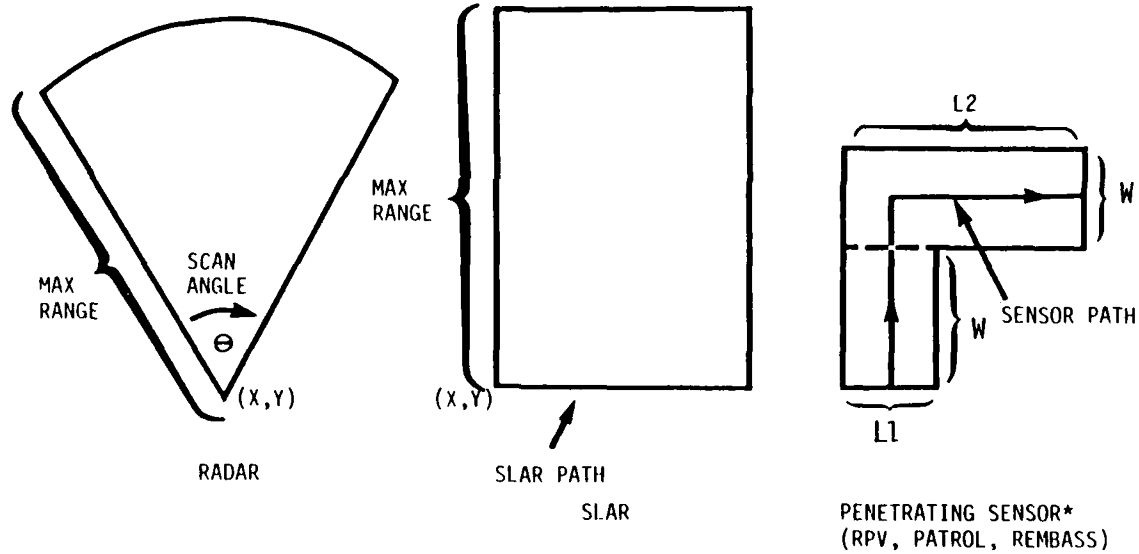
(NOT USED)

Section IV. SENSOR CHARACTERISTICS

US ARMY

CONCEPTS ANALYSIS AGENCY

SENSOR PATTERN TYPES



* PENETRATING SENSOR COVERAGE CONSISTS OF 1 OR MORE RECTANGLES.

A10

SENSOR PATTERN TYPES

TADER treats the coverage pattern of a sensor as a user-defined area with a specific shape. The allowable shapes and defining parameters for various types of sensors are as follows:

STANO RADAR - The allowable shape is a pie wedge representing the area covered by a radar scanning back and forth through a specified scan angle. The maximum range and the scan angle determine the coverage pattern. The sensor location determines the location of the wedge. The center axis of radar scan (and its pattern) is always modeled as perpendicular to the FLOT. This type of coverage pattern also characterizes stationary forward observers.

SLAR (Standoff) - The standoff SLAR is treated as traversing the entire width of the sector. Its coverage pattern is a rectangle with width, parallel to the FLOT, equal to the sector width and with length, perpendicular to the FLOT, equal to the maximum range of the sensor.

PENETRATING SENSOR - Penetrating sensors include remotely piloted vehicles (RPVs) and patrols (short-range and long-range) as well as overflying aircraft and strings of emplaced sensors (e.g., REMBASS). TADER represents coverage for *a system of* penetrating sensors as a set of rectangles with user-specified length, width, and location within a sector. All rectangle widths are parallel to the FLOT and all lengths are perpendicular to it. As shown in the illustration, a sensor path is broken into linear sections within the rectangles. When a penetrating sensor system is designed to detect artillery/mortar firings (e.g., FAALS), it is designated a counterbattery penetrator type of sensor.

GENERAL CASE
SENSOR SYSTEM COVERAGE INPUTS

- RADAR
  - NUMBER DEPLOYED
  - LOCATION OF EACH SENSOR IN SYSTEM RELATIVE TO FLOT
  - SCAN ANGLE (COMMON TO EACH RADAR IN SYSTEM)
  - MAXIMUM RANGE (COMMON TO EACH RADAR IN SYSTEM)
- SLAR (STANDOFF)
  - NUMBER OF MISSIONS (TRAVERSES OF THE SECTOR ON A PATH PARALLEL TO FLOT
  - STANDOFF DISTANCE OF PATH FROM FLOT
  - MAXIMUM RANGE PERPENDICULAR TO PATH (AND FLOT)
- PENETRATING SYSTEM (RPV, PATROL, ACFT, REMBASS)
  - NUMBER OF COVERAGE PATTERNS (PER MISSION)
  - LOCATION AND DIMENSIONS OF COVERAGE PATTERNS

A11

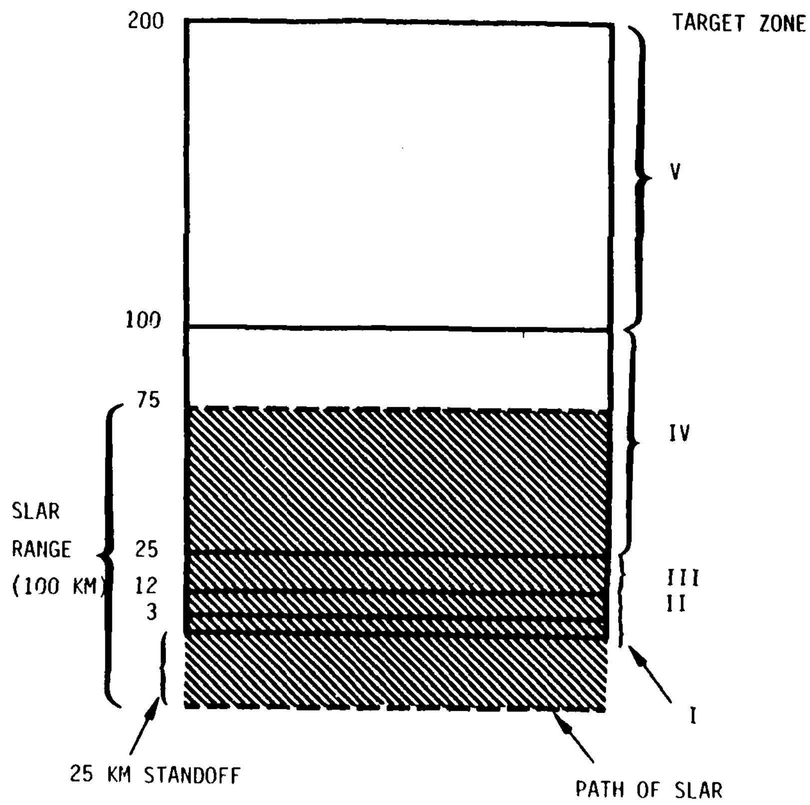
GENERAL CASE - SENSOR SYSTEM COVERAGE INPUTS

A sensor system consists of a collection of deployed sensors of a single type. A scenario may treat several systems of various types. All sensors within a system have identical characteristics except for location, which can be user-specified for each sensor of a system.

EXAMPLE CASE - SENSOR SYSTEM COVERAGE INPUTS

SLAR

NUMBER MISSIONS= 2
STANDOFF=25 KM
MAX RANGE=100 KM



A12

EXAMPLE CASE - SENSOR SYSTEM COVERAGE INPUTS

The example case treats two SLAR missions traversing the sector at a standoff of 25 km from the FLOT. The scanning range of the SLAR (measured perpendicular to its path) is 100 km. The coverage pattern is shown in the accompanying illustration. Sensor coverage between the SLAR and the FLOT is ignored because there is no associated target zone. In the illustrations, target zones are labelled with Roman numerals.

US ARMY

CONCEPTS ANALYSIS AGENCY

SYSTEM DEGRADATION INPUT FACTORS

GENERAL CASE

- FOR EACH SENSOR SYSTEM S, DEFINE

PWEA(S) = WEATHER DEGRADATION FACTOR
PWIND(S) = WIND DEGRADATION FACTOR
PSMO(S) = SMOKE DEGRADATION FACTOR
PCPF(S) = CREW PERFORMANCE DEGRADATION FACTOR
PLOS(L,S) = PROB OF LINE OF SIGHT (SYSTEM S, SENSOR ZONE L)
FA(S) = PROB SENSOR IS AVAILABLE
FS(S) = PROB SENSOR SURVIVES

EXAMPLE CASE (S = SLAR)

PWEA(S) = 1.00
PWIND(S)= 1.00
PSMO(S) = .90
PCPF(S) = 1.00
FA(S) = .90
FS(S) = .99

EXAMPLE PLOS(L,S) BY SENSOR ZONE

I	II	III	IV	V
.90	.85	.80	.70	.50

A13

SYSTEM DEGRADATION INPUT FACTORS

Sensor capability is affected by various environmental factors in the vicinity of the sensor. These are modeled by applying input multipliers to the inherent detection probabilities. Each sensor system, S, (and, accordingly, each identical sensor of that system) has an associated user-input degradation factor for each effect modeled, as follows:

(1) PWEA(S) = Average extent to which adverse weather will degrade sensor operation.

(2) PWIND(S) = Average extent to which wind conditions will degrade sensor operation.

(3) PSMO(S) = Average extent to which smoke on the battlefield will degrade sensor performance.

(4) PCPF(S) = Average extent to which unsatisfactory crew performance will degrade sensor operation.

(5) PLOS(L,S) = For each sensor zone L, the probability that a target in sensor zone L is visible to a sensor of system S in clear weather and under ideal conditions. The nature of intervening terrain in target zones affects the ability of a sensor to observe targets. The LOS multiplier in TADER is represented as an average value over a zone.

(6) FA(S) = Probability that a sensor of system S is available, i.e., deployed and able to operate. Factors considered in generating this input are set-up time, take-down time, rates of movement for relocation, and downtime during periods of darkness.

(7) FS(S) = Probability that a sensor of system S survives throughout the scanning period. The probability of a system not surviving is defined as the product of the probability of the system being detected by the opposing force and the probability of the system being destroyed, if detected.

The values of the above factors for the example case are shown in the chart. It is important to note that the first four factors are relative effectiveness factors because they each represent an expected value for a system's average performance, with respect to its nondegraded state, taking into account the severity and frequency of each condition.

INHERENT SENSOR DETECTION DATA

GENERAL CASE

- PDET(J,L,S) = INHERENT PROBABILITY THAT A SINGLE MISSION (OR SENSOR) OF SENSOR SYSTEM S DETECTS A SINGLE TARGET ELEMENT OF TYPE J UNDER IDEAL CONDITIONS IN SENSOR ZONE L

EXAMPLE CASE

PDET(J,L,S), BY SENSOR ZONE (L)

ELT(J)	I	II	III	IV	V
J = 1	.00	.00	.00	.00	.00
2	1.00	.99	.90	.60	.50
3	1.00	.99	.90	.60	.50
4	.00	.00	.00	.00	.00
5	.00	.00	.00	.00	.00

A14

INHERENT SENSOR DETECTION DATA

The input inherent probability of detection represents the capability of a single sensor of a system to detect a single target element under ideal conditions. These values vary as a function of range. However, the TADER methodology divides the sensor range spectrum into sensor zones and treats the inherent probability of detection as uniform within each zone. In general, the inherent probability of detection is *not* a real-world value. It is only a standard baseline which is transformed by the methodology, through adjustment factors, into values appropriate to various "real-world" target environment conditions.

The example case values show SLAR detection capability only for element types 2 and 3 (wheeled and tracked vehicles). The detection probabilities decrease with increasing range (increasing index of sensor zone).

CONCEPTS ANALYSIS AGENCY

SENSOR ACTIVITY/ENVIRONMENT FACTORS

GENERAL CASE

- FOR EACH SENSOR SYSTEM S, TARGET ELEMENT TYPE J, SENSOR ZONE L AND TARGET ACTIVITY/ENVIRONMENT COMBINATION A/E (ACTIVITY A WITH ENVIRONMENT E), DEFINE

FC(J,L,S,A/E) = FRACTION OF INHERENT DETECTION CAPABILITY APPLICABLE TO A SINGLE SENSOR OF SYSTEM S VS A SINGLE ELEMENT OF TYPE J IN SENSOR ZONE L

EXAMPLE CASE

- FOR SENSOR SYSTEM S (SLAR)
  - ACTIVITY/ENVIRONMENT FACTORS (FC(J,L,S,A/E)) APPLICABLE TO ALL SENSOR ZONES

	FC(J,L,S,A/E), BY ELEMENT TYPE (J)				
TGT ACTIVITY/ENVIRONMENT	J = 1	2	3	4	5
A/E = 1 (MOVING/OPEN)	.82	.82	.82	.82	.82
A/E = 2 (MOVING/NOT OPEN)	.40	.40	.40	.40	.40
A/E = 3 (STATIC/OPEN)	.20	.20	.20	.20	.20
A/E = 4 (STATIC/NOT OPEN)	.10	.10	.10	.10	.10

A15

SENSOR ACTIVITY/ENVIRONMENT FACTORS

The input inherent detection probabilities are based on ideal conditions. Since targets are rarely in such an environment, additional detection probability distributions must be defined for a range of nonideal real world conditions. Two primary conditions affecting sensor detection capability are target environment and target activity. A target which is moving in open terrain is usually easier to detect than when it is stationary in a wooded or urban area.

Instead of directly defining for each sensor type a degraded (relative to ideal conditions) detection probability distribution for each A/E state, modifiers of the inherent probabilities are input. Each modifier for each sensor type is a function of target element type, sensor zone and activity/environment. For each activity/environment, A/E, the method defines the product of the modifier and the inherent detection probability as the detection probability applicable to that activity/environment combination. The modifier, therefore, can be considered to represent the fraction of ideal (inherent) detection capability remaining when the target is in activity/environment A/E. Exactly four modifiers, one for each A/E state, must be input for each PDET(J, L, S) input value.

The activity/environment modifiers used in the example case are also shown in this chart. The representation is compressed because, in the model input, five values, one for each sensor zone, would be input for each value shown in the table. Since the table values for this example are assumed applicable to all sensor zones, it suffices to display only the values shown. The entries used imply that a moving target in the open is most readily detectable by the example SLAR (FC(...1) = .82), while one which is static and not in the open is least detectable (FC(...4) = .10). (While one might expect the A/E condition under which a sensor is most capable to be reflected by an FC = 1.0, the numbers shown in the chart were selected without that consideration, but will suffice for purposes of the example.)

(NOT USED)

Section V. POTA CALCULATION OVERVIEW

(NOT USED)

OVERVIEW - UNIT POTA CALCULATION IN TARGET ZONE

The end product of TADER is the unit POTA for a target unit randomly located in a target zone searched by all scenario systems. This zone unit POTA is determined in the following manner.

(1) The target zone is partitioned into grid squares of uniform (input-specified) size.

(2) For each deployed sensor of each system, a single-sensor unit POTA for each grid square is computed, based on the target unit being in that grid square and scanned by that sensor. This is the probability that the sensor detects the target as lucrative.

(3) For each system, a single-system POTA for each grid square is computed by combining single-sensor POTAs. This is the probability that the system detects the target as lucrative.

(4) Over all noncounterfire systems, the noncounterfire unit POTA for each grid square is computed by combining single-system POTAs versus unit. This is the probability that at least one noncounterfire system detects the unit as lucrative.

(5) Over all counterfire systems, the counterfire unit POTA, based on volleys fired by artillery/mortar element types (J = 4 or 5), for each grid square is computed by combining single-system POTAs versus unit. This is the probability that at least one counterfire system detects the unit as lucrative.

(6) The combined unit POTA for each grid square is computed by combining the noncounterfire unit POTA with the counterfire unit POTA. This is the probability that at least one system detects the target unit as lucrative.

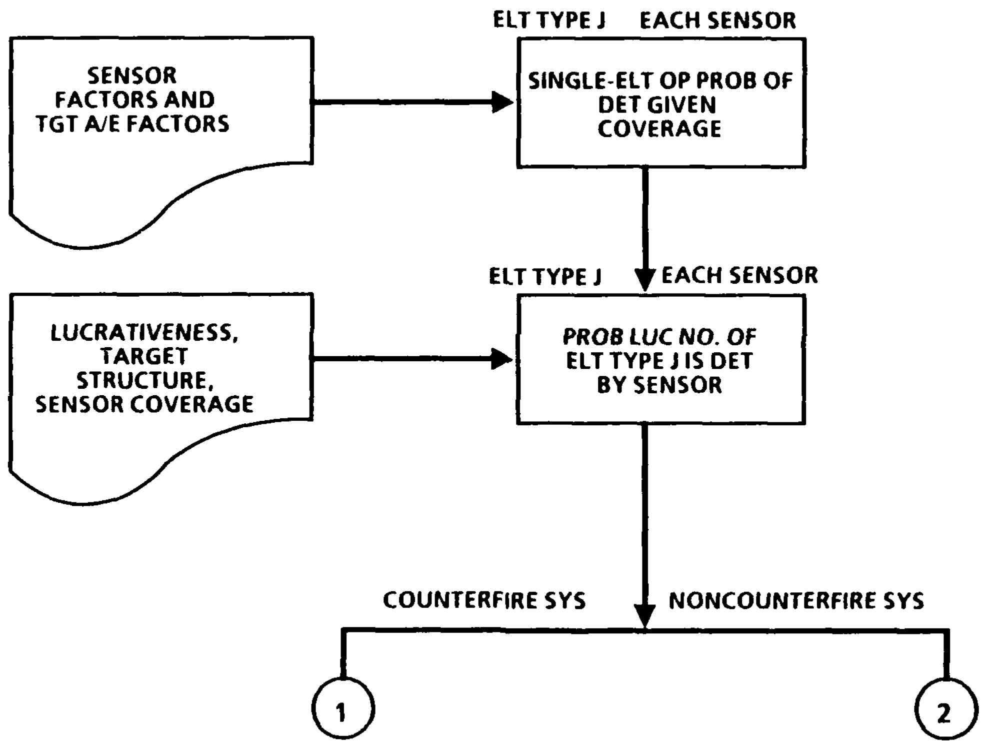
(7) The unit POTA for the target zone is computed by averaging the grid square unit POTAs over all grid squares in the target zone. Averaging takes into account the effects of random target location over the target zone.

Stages (2) through (6) above are described in more detail in the following two charts.

US ARMY

CONCEPTS ANALYSIS AGENCY

OVERVIEW - UNIT POTA CALCULATION FOR A GRID SQUARE



A16

OVERVIEW - UNIT POTA CALCULATION FOR A GRID SQUARE

Assuming that a target zone is partitioned into uniform grid squares, this chart and its successor summarize the sequence of calculations which determine a unit POTA for a grid square. These calculations are described in detail on other charts, which are referenced below by their numbers.

SINGLE-ELT OP PROB OF DET GIVEN COVERAGE - The various sensor degradation factors (A13), the inherent detection probabilities (A14), and the activity/environment (A15) factors are combined to form for each sensor its operational probabilities of detecting each target element in the scanned grid square (see A18, A20, A21, and A23).

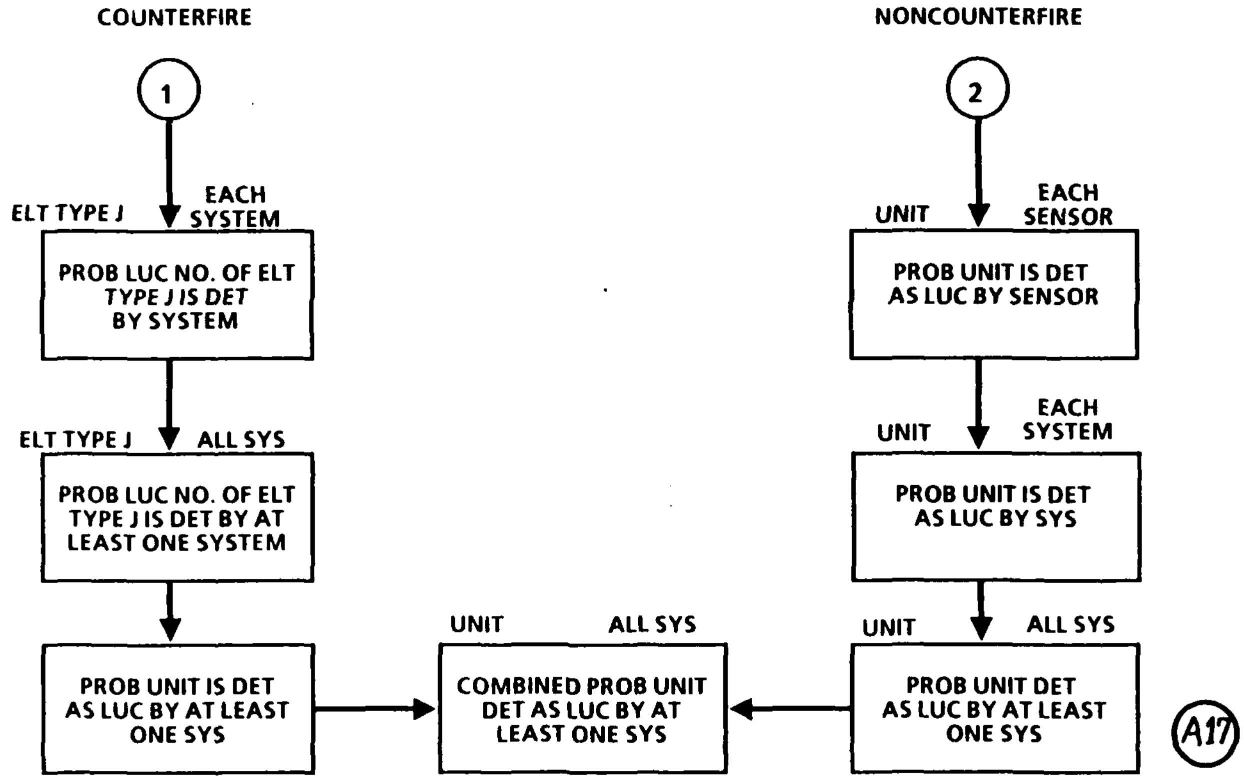
PROB LUC NO. OF ELT TYPE J IS DET BY SENSOR - The single-sensor/single-element operational detection probability and the number of target elements of a specified type in a unit (A5) define a binomial probability distribution for the number of elements detected from a scan of the unit by a specific single sensor. The binomial is used to calculate the probability that at least a specified number of elements of the specified type, based on input TOE (A5), coverage (A11), and lucrativeness thresholds (A27 and A28), are detected by the specific sensor scanning the element type in the unit and grid square (see A25, A29, A31, and A37).

From this point on, calculations for counterfire systems are done separately from those for noncounterfire systems until the final step, when they are combined into a final unit POTA for all systems.

US ARMY

CONCEPTS ANALYSIS AGENCY

OVERVIEW - UNIT POTA CALCULATION FOR A GRID SQUARE



OVERVIEW - UNIT POTA CALCULATION FOR A GRID SQUARE

Calculations proceed separately along two branches, one for counterfire systems, the other for noncounterfire systems. They are combined in a last step. The logic in each branch is:

For counterfire systems:

PROB LUC NO. OF ELT TYPE J IS DET BY SYSTEM - Using statistical independence, single-sensor POTAs for each artillery/mortar element type (J=4 or 5) are combined over all sensors comprising a system to form a single-system unit POTA for the element type in the grid square (see A38).

PROB LUC NO. OF ELT TYPE J IS DET BY AT LEAST ONE SYSTEM - Using statistical independence, the single-system POTAs are combined over all systems to form an overall unit POTA for each artillery/mortar element type in the unit and grid square (see A39).

PROB UNIT IS DET AS LUC BY AT LEAST ONE SYS - Using statistical independence, the single-system POTAs are combined over all systems to form an overall unit POTA in the grid square (see A40).

For noncounterfire systems:

PROB UNIT IS DET AS LUC BY SENSOR - The single sensor detection probabilities for each element type in a unit are combined over all element types comprising a unit to form a single-sensor probability of lucrative detection (POTA) of the unit in the grid square (see A33).

PROB UNIT IS DET AS LUC BY SYS - Using statistical independence, the single-sensor POTAs are combined over all sensors comprising a system to form a single-system POTA of the unit in the grid square (see A35).

PROB UNIT DET AS LUC BY AT LEAST ONE SYS - Using statistical independence, the single-system POTAs are combined over all systems to form an overall unit POTA in the grid square (see A36).

In the final step, the overall unit POTA from all noncounterfire systems is combined with the overall unit POTA from all counterfire systems. The result is a final unit POTA from all systems for a unit located in a specific grid square (see A41).

(NOT USED)

Section VI. OPERATIONAL PROBABILITY OF DETECTION, GIVEN COVERAGE

GENERAL CASE

OPERATIONAL PROBABILITY OF DETECTION, GIVEN COVERAGE

- CALCULATE FOR EACH J, L, S, AND A/E,

PD(J,L,S,A/E) = PROBABILITY OF OPERATIONAL DETECTION, GIVEN COVERAGE BY A SINGLE AVAILABLE SENSOR OF TYPE S SCANNING A SINGLE TARGET ELEMENT OF TYPE J IN ACTIVITY/ENVIRONMENT A/E IN SENSOR ZONE L

$$= \underbrace{\mathrm{PDET}(J,L,S)}_{\text{INHERENT DET CAPABILITY}} \times \underbrace{\mathrm{FC}(J,L,S,A/E)}_{\text{CAPABILITY MODIFIER DUE TO A/E}} \times \underbrace{\mathrm{DEG}(S,L)}_{\text{SENSOR DEGRADATION FACTOR}}$$

WHERE DEG(S,L) = PWEA(S) x PSMO(S) x PCPF(S) x PWIND(S) x PLOS(S,L)

A18

GENERAL CASE - OPERATIONAL PROBABILITY OF DETECTION, GIVEN COVERAGE

The various sensor degradation factors (Chart A13), the sensor capability activity/environment factors (Chart A15) and the inherent detection probability (Chart A14) are combined to form an operational probability of detection, given coverage, of a single target element by a single available sensor for each activity/environment condition. These factors multiplicatively adjust the inherent detection probability to reflect a variety of "real-world" environments and sensor operating conditions. This calculation assumes that the scanned element is "covered," i.e., lies within range and field of view of the scanning sensor and that the scanning sensor is available and surviving. These values of PD(J, L, S, A/E) are "building blocks" for the final POTA values, since they define detectability (given coverage and sensor availability) for every possible single-sensor/single-target element combination.

EXAMPLE CASE

OPERATIONAL PROBABILITY OF DETECTION, GIVEN COVERAGE

- FOR THE SLAR SYSTEM (S) AND SCANNING SENSOR ZONE L=4, PD(J,L,S,A/E), THE OPERATIONAL PROBABILITY OF DETECTION (SINGLE SENSOR VS SINGLE ELT) GIVEN COVERAGE OF ELT TYPE J IN SENSOR ZONE L AND ACTIVITY/ENVIRONMENT A/E IS:

A/E	J	PDET(J,L,S)	x	FC(J,L,S,A/E)	x	PWEA(S)	x	PSMO(S)	x	PCPF(S)	x	PLOS(S,L)	=	PD
1	1,4,5	0	x	.82	x	1.00	x	.90	x	1.00	x	.70	=	0
	2,3	.60	x	.82	x	1.00	x	.90	x	1.00	x	.70	=	.310
2	1,4,5	0	x	.40	x	1.00	x	.90	x	1.00	x	.70	=	0
	2,3	.60	x	.40	x	1.00	x	.90	x	1.00	x	.70	=	.151
3	1,4,5	0	x	.20	x	1.00	x	.90	x	1.00	x	.70	=	0
	2,3	.60	x	.20	x	1.00	x	.90	x	1.00	x	.70	=	.076
4	1,4,5	0	x	.10	x	1.00	x	.90	x	1.00	x	.70	=	0
	2,3	.60	x	.10	x	1.00	x	.90	x	1.00	x	.70	=	.038

L=4 THROUGHOUT THE ABOVE CALCULATION.ANALOGOUS COMPUTATIONS APPLY FOR OTHER VALUES OF L.

A19

EXAMPLE CASE - OPERATIONAL PROBABILITY OF DETECTION, GIVEN COVERAGE

This chart shows the calculation of the PD values for the example case, restricted to sensor zone IV. The example case produces the same values of PD for several values of J (target element index).

GENERAL CASE

WEIGHTED OP PROBABILITY OF DETECTION, GIVEN COVERAGE (NONCOUNTERFIRE)

- FOR EACH COMBINATION OF SENSOR ZONE L, TARGET ZONE K, SYSTEM S, UNIT I, AND TGT ELEMENT TYPE J COMPUTE

PODT(I,J,K,L,S) = AVERAGE OPERATIONAL PROBABILITY OF DETECTION BY A SINGLE AVAILABLE SENSOR (IN SYSTEM S) OF A SINGLE ELT (OF TYPE J IN UNIT I) WITHIN THAT SENSOR'S RANGE (COVERAGE) AND LOCATED IN SENSOR ZONE L AND TARGET ZONE K

$$= \sum_{A/E=1}^{4} \mathrm{FACT}(I,J,K,A/E) \times \mathrm{PD}(J,L,S,A/E)$$

WHERE FACT(I,J,K,A/E) = FRACTION OF TARGET ELEMENTS IN EACH ACTIVITY/ENVIRONMENT STATE (CHART A8)

A20

GENERAL CASE - WEIGHTED OPERATIONAL PROBABILITY OF DETECTION, GIVEN COVERAGE (NONCOUNTERFIRE)

The "building block" PD values must be weighted by the activity/environment frequencies to form the PODT array defined in this chart. The result is the average probability that a single available and surviving sensor (of system type S) will detect a single element of type J in unit I located in sensor zone L and target zone K, given that the element is within scanning range (coverage scan) of the sensor. The PODT values serve as building blocks of the final overall unit POTA in a target zone.

GENERAL CASE

WEIGHTED OP PROBABILITY OF DETECTION, GIVEN COVERAGE (COUNTERFIRE)

- A SINGLE VOLLEY DETECTION PROBABILITY IS COMPUTED BASED ON SENSOR AVAILABILITY (FA(S)) AND SURVIVABILITY (FS(S)) BEING THE SAME FOR ALL ROUNDS IN A VOLLEY.

- FOR EACH COMBINATION OF SENSOR ZONE L, TGT ZONE K, SYSTEM S, UNIT I AND FIRING ELT TYPE J=4,5 COMPUTE

  - *PODR(I,J,K,L,S)* = AVG OP PROB OF DETECTION BY A SINGLE AVAILABLE AND SURVIVING SENSOR (OF SYS S) OF A SINGLE RD (FIRED BY ELT TYPE J IN UNIT I) WITHIN SENSOR COVERAGE IN SENSOR ZONE L AND TGT ZONE K.

$$= \sum_{A/E=1}^{4} \mathrm{FACT}(I,J,K,A/E) \times \mathrm{PD}(J,L,S,A/E)$$

  - PODT(I,J,K,L,S) = AVG OP PROB OF DET OF A VOLLEY FIRED BY ELT TYPE J

$$= \mathrm{FA}(S) \times \mathrm{FS}(S) \times (1.-(1.-\mathrm{PODR}(I,J,K,L,S))^{R})$$

WHERE R=IRPS(I,J) = NUMBER OF ROUNDS IN A VOLLEY

PD(J,L,S,A/E)=SINGLE ROUND PROB OF OP DET, GIVEN COVERAGE, BY SINGLE SENSOR (CHART A18)

FACT(I,J,K,A/E)=ACTIVITY/ENVIRONMENT FACTOR (CHART A8)

A21

GENERAL CASE - WEIGHTED OPERATIONAL PROBABILITY OF DETECTION, GIVEN COVERAGE (COUNTERFIRE)

Target elements consisting of fired volleys of arty/rocket/mortar launchers (element types 4 and 5) have slightly different treatment from that for other element types. For a single volley, detection probability by a single sensor is computed based on:

(1) The sensor availability and survivability being the same for all rounds in a volley.

(2) The volley detection being defined as the detection of at least one round of the volley.

The net effect is that PODT, the weighted operational probability of detection, given coverage, of a volley, is the product of the sensor survivability, the sensor availability and the probability that at least one round of an in-range volley is detected.

EXAMPLE CASE

WEIGHTED OP PROBABILITY OF DETECTION, GIVEN COVERAGE

- FOR SENSOR ZONE IV, TARGET ZONE IV, SLAR SYSTEM S, UNIT 1 AND TGT ELEMENT TYPES J=2 AND 3

		FACT(I,J,K,A/E)		PD(J,L,S,A/E)	
PODT(I,J,K,L,S)	=	.05	x	.310	(A/E=1)
	+	.05	x	.151	(A/E=2)
	+	.10	x	.076	(A/E=3)
	+	.80	x	.038	(A/E=4)
	=	.061			

PODT(I,J,K,L,S) = 0 FOR J=1, 4, OR 5

- ANALOGOUS CALCULATIONS APPLY FOR OTHER VALUES OF K AND L.

A22

EXAMPLE CASE - WEIGHTED OPERATIONAL PROBABILITY OF DETECTION, GIVEN COVERAGE

This chart shows the calculation of PODT values for the example case, which is restricted to sensor zone IV and target zone IV. In the general case, a PODT value is calculated for every combination of unit type I, element type J, target zone K, sensor zone L and sensor system S.

(NOT USED)

Section VII. SINGLE-SENSOR/SINGLE GRID SQUARE BASICS

CONCEPTS ANALYSIS AGENCY

GENERAL CASE-OPERATIONAL PROBABILITY OF DETECTION
SINGLE SENSOR/SINGLE ELT/SINGLE GRID SQUARE

- PARTITION EACH TARGET ZONE K INTO A GRID COMPRISED OF UNIFORM GRID SQUARES G=1, 2, 3, ... NG(K)

- FOR A SINGLE TGT ELEMENT (TYPE J) IN UNIT I LOCATED IN A GRID SQUARE G, AND FOR A SINGLE SENSOR, M, OF SYSTEM S, THE ASSOCIATED OPERATIONAL PROBABILITY OF DETECTION IS DEFINED AS:

POD(I,J,S,M,G)=0 IF GRID SQUARE G IS NOT IN COVERAGE REGION OF SENSOR M
= PODT(I,J,K(G),L(G),S) IF G IS IN THE COVERAGE REGION OF SENSOR M

WHERE L(G) = SENSOR ZONE CONTAINING GRID SQUARE G
K(G) = TARGET ZONE CONTAINING GRID SQUARE G

A23

GENERAL CASE - OPERATIONAL PROBABILITY OF DETECTION, SINGLE SENSOR/SINGLE ELT/SINGLE GRID SQUARE

Each target zone is partitioned into uniform grid squares of input-specified size. Effects of coverage and detection are treated as uniform within each grid square. Given a partition of a target zone into grid squares, each square is processed as follows to yield a single-element probability of detection applicable to a single sensor scanning a single element located in that square. For each emplaced sensor, M, of each system:

a. A determination is made whether the center of the grid square is in the coverage region (within scanning range) of the emplaced sensor.

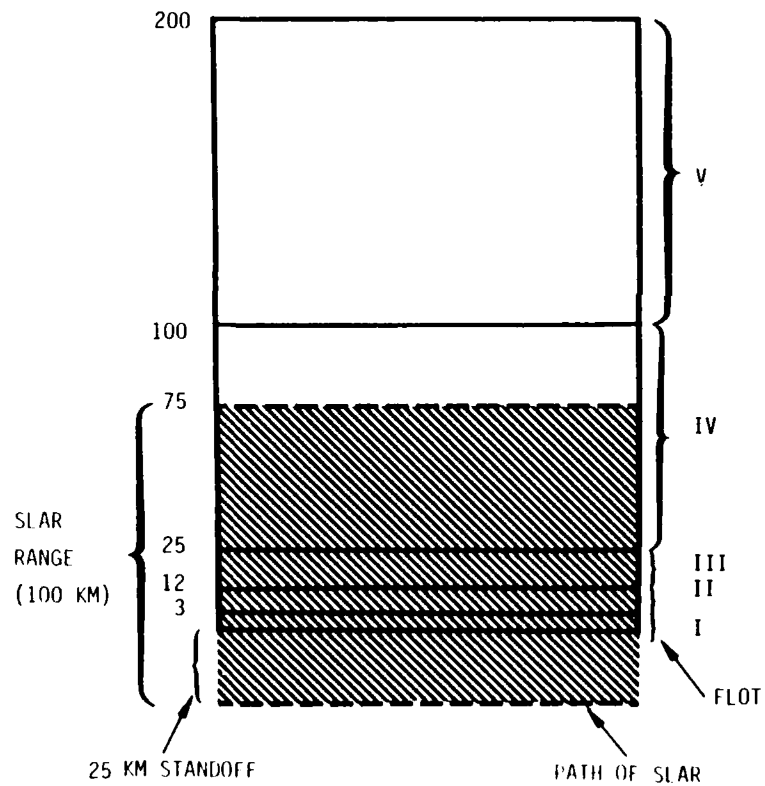
b. If the center of the grid square is *not* in the coverage region, the single-element probability of detection (POD) for sensor M in the grid square is zero.

c. If the center of the grid square is in the coverage region, the single-element probability of detection, POD, is set equal to the (already calculated) value of PODT for the combination of target unit (I), element type (J), sensor system type (S), target zone (K) containing this grid square (G) and sensor zone (L) (of sensor M) containing this grid square.

After the above processing, POD contains the single-element/single-sensor operational detection probability for each sensor scanning each element in each grid square. These will be combined to reflect a multielement/multisensor POTA.

EXAMPLE CASE - OPERATIONAL PROBABILITY OF DETECTION

SINGLE SENSOR/SINGLE ELT/SINGLE GRID SQUARE



- HATCHED AREA IS COVERAGE REGION
- COVERAGE IN TARGET ZONE IV(K=4) IS IN SENSOR ZONE L=4 (25-100 KM FROM SLAR)
- FOR M=1 MISSION OF SYSTEM S SCANNING ELT TYPE J IN UNIT I
  - FOR J=2,3 AND FOR ALL GRID SQUARES IN HATCHED REGION WITHIN TARGET ZONE IV

    POD(I,J,S,M,G) = 0.61
  - FOR J=2,3 AND FOR ALL GRID SQUARES NOT IN HATCHED REGION

    POD(I,J,S,M,G) = 0

  - FOR J=1,4 AND 5

    POD(I,J,S,M,G) = 0

A24

EXAMPLE CASE - OPERATIONAL PROBABILITY OF DETECTION, SINGLE SENSOR/SINGLE ELT/SINGLE GRID SQUARE

This chart illustrates the results of calculations of the single-element/single-sensor operational probability of detection for each grid square of the example case. Each target zone is assumed partitioned into grid squares 1 km on a side. Sensor coverage is as shown. The only meaningful cases are for element types 2 and 3, which yield a value (of POD = PODT) of 0.061 for all grid squares of target zone IV within 75 km of the FEBA and a value of 0 for all other squares of the zone.

GENERAL CASE

SINGLE-SENSOR PROBABILITY OF DETECTING EXACTLY N TARGET ELEMENTS IN A GRID SQUARE

- FOR EACH I, J, S,M,G (UNIT TYPE, ELT TYPE, SYSTEM, SENSOR, GRID SQUARE):

NE = TOTAL TARGET ELEMENTS OF TYPE J IN UNIT I = PTGT(I,J,K), WHERE K IS INDEX OF TGT ZONE CONTAINING G

P(I,J,S,M,G,N)= OPERATIONAL PROBABILITY OF SENSOR M OF SYSTEM S DETECTING EXACTLY N TARGET ELEMENTS IN GRID SQUARE G, FOR N=0, 1, 2...NE

$$P(I,J,S,M,G,N) = \binom{NE}{N} \times POD(I,J,S,M,G)^{N} \times (1-POD(I,J,S,M,G))^{NE-N}$$

NR OF SPECIFIC COMBIN OF N ELTS	PROB THAT ANY N SPECIFIC ELTS WILL BE DETECTED IN G	PROB THE OTHER (NE-N) ELTS WILL NOT BE DETECTED IN G

= Nth TERM OF BINOMIAL DISTRIBUTION WITH DEFINING PARAMETERS NE AND POD(I,J,S,M,G)

A25

GENERAL CASE - SINGLE SENSOR PROBABILITY OF DETECTING EXACTLY N TARGET ELEMENTS IN A GRID SQUARE

Given a grid square, G, let K denote the target zone in which G lies. For each element type and for an arbitrary nonnegative integer N less than or equal to PTGT(I, J, K) (= number of target elements of type J in unit I and target zone K), we now calculate P(I, J, S, M, G, N) = the operational probability that exactly N target elements of type J in unit I are detected by the sensor M of system S in grid square G. Combinational probability theory applied to the single-element/single-sensor POD values enables generalizing from single-element detection values to multielement (e.g., N elements) detection values through use of the binomial probability distribution. P(I, J, S, M, G, N) is the Nth term of the binomial distribution B(NE, POD) with NE (=PTGT(I, J, K)) terms and with the single event (i.e., single-element detection) probability, POD (=POD(I, J, S, M, G)). Note that P(I, J, S, M, G, N) applies to only a single sensor and a single element type. Further combination is required to construct a multisystem POTA applicable to a unit.

EXAMPLE CASE

SINGLE-SENSOR PROBABILITY OF DETECTING EXACTLY N TARGET ELEMENTS IN A GRID SQUARE

- FOR ELT TYPE J=2 OF TGT TYPE I IN A COVERED GRID SQUARE,G, OF ZONE K=4, PTGT(I,J,K) = 10 (CHART A7) AND POD(I,J,S,M,G) = .061 (CHART A24), SCANNED BY SENSOR M OF SYSTEM 1

N	P(I,2,S,M,G,N)	= OP PROB OF DETECTING EXACTLY N ELTS
0	$\binom{10}{0} \times (.061)^{0} \times (1. - .061)^{10-0}$	= .533
1	$\binom{10}{1} \times (.061)^{1} \times (1. - .061)^{9}$	= .346
2		= .101
3		= .018

- FOR ELT TYPE J=3 IN ZONE K=4, PTGT(I,J,K) = 20 (CHART A7), POD(I,J,S,M,G) = .061 (CHART A24) AND

	N = 0	N = 1	N = 2	N = 3	N = 4	N = 5
P(I,3,S,M,G,N) =	.284	.369	.228	.089	.024	.006

A26

EXAMPLE CASE - SINGLE SENSOR PROBABILITY OF DETECTING EXACTLY N TARGET ELEMENTS IN A GRID SQUARE

This chart shows the calculation of P(I, J, S, M, G, N) for several values of N in the example case. Since the sum of all terms of a binomial distribution must equal 1.00, it is clear that essentially all nonzero terms are shown (because their sum, for each element type, is 1.00).

(NOT USED)

Section VIII. NONCOUNTERFIRE SENSOR "OR"/"AND" LUCRATIVENESS CONSIDERATIONS

'OR' TGT LUCRATIVENESS BY TGT ELT TYPE

- GENERAL CASE - FOR A SPECIFIED TARGET ELEMENT TYPE J IN A UNIT I, THE ASSOCIATED POTA CAN BE RESTRICTED TO DETECTIONS OF A MINIMUM SIZE BY DEFINING THE 'OR' LUCRATIVENESS FOR ALL ELEMENT TYPES EXCEPT FIRED ARTY/MORTAR ROUNDS

  THRES(I,J,K) = MINIMUM FRACTION OF TOE (PTGT(I,J,K) FROM CHART A7 FOR ELEMENT TYPE J IN UNIT I THAT MUST BE DETECTED* IN TARGET ZONE K TO CLASSIFY THE DETECTION AS LUCRATIVE WITH RESPECT TO 'OR' LUCRATIVENESS

- EXAMPLE CASE - SET THRES(I,J,K) = .20 (20 PERCENT OF TOE) FOR ALL J

- FOR FIRING ARTY/MORTAR (FROM ELT TYPES J=4,5), ITHS(I,J) = MINIMUM NUMBER OF VOLLEYS OF ELT J ROUNDS IN UNIT I THAT MUST BE DETECTED TO CLASSIFY THE DETECTION AS LUCRATIVE.

A27

*COMBINED DETECTIONS FROM ALL SENSORS OF A SYSTEM SCANNING UNIT I IN ONE SEARCH PERIOD.

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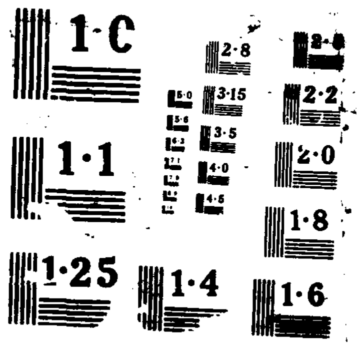
UNCLASSIFIED F/G 17/11 NL


1.0
2.8
2.5
3.15
2.2
3.5
2.0
1.1
4.0
4.5
1.8
1.25
1.4
1.6

"OR" TARGET LUCRATIVENESS BY TARGET ELEMENT TYPE

In the simplest case, detection of a target unit is equivalent to detection of at least one target element, e.g., a tank unit treated as detected if only a single tank is detected. However, TADER enables a user to screen out unsuitably small target clusters by applying user-input target lucrativeness thresholds of one or more elements of the type in question. For all element types except firing arty/mortar, the specified lucrativeness threshold is based on the minimum fraction of the TOE of those element types that must be detected.

For the example case, an "OR" lucrativeness threshold of 0.20 (20 percent of element TOE) was set.

There are two types of lucrativeness thresholds in TADER, "OR" lucrativeness thresholds and "AND" lucrativeness thresholds. An "OR" lucrativeness threshold is part of a set of "OR" thresholds, one threshold specified for each element type. Each "OR" threshold determines a minimum detection quantity such that combined detections from a system scanning a target unit are deemed lucrative if they exceed the minimum detection quantity for at least one element type. The minimum detection quantity specified by a lucrativeness threshold is determined as:

(1) For all element types except firing arty/mortar, the product of the input threshold fraction and the element TOE for the unit.

(2) For firing arty/mortar (from element types 4 and 5), the (input) volleys needed to classify the detection as lucrative.

CONCEPTS ANALYSIS AGENCY

'AND' TGT LUCRATIVENESS BY TGT ELT TYPE

- GENERAL CASE - FOR TARGET ELEMENT TYPE J=2 OR 3 IN A UNIT I, THE ASSOCIATED POTA CAN BE RESTRICTED TO DETECTIONS OF A MINIMUM SIZE BY DEFINING THE 'AND' LUCRATIVENESS

ATHRES(I,J,K) = MINIMUM FRACTIONS OF TOE (PTGT(I,J,K) FROM CHART A7) FOR ELEMENT TYPES 2 AND 3 IN UNIT I THAT MUST BOTH BE DETECTED* IN TARGET ZONE K TO CLASSIFY THE DETECTION AS LUCRATIVE WITH RESPECT TO 'AND' LUCRATIVENESS

- EXAMPLE CASE - SET ATHRES(I,J,K) = .20 (20 PERCENT OF TOE) FOR J=2 AND J=3

*COMBINED DETECTIONS FROM ALL SENSORS OF A SYSTEM SCANNING UNIT I IN ONE SEARCH PERIOD.

A28

"AND" TGT LUCRATIVENESS BY TGT ELT TYPE

An "AND" lucrativeness threshold is specified only for element types 2 and 3 (wheeled and tracked vehicles). Combined detections (of element types 2 and 3) for a system scanning a target unit are deemed lucrative under the "AND" lucrativeness criterion if the detections of both element types (2 and 3) exceed the threshold quantities (= product of lucrativeness fraction and TOE) for the element types. An "AND" lucrativeness threshold is specified as less than or equal to the "OR" threshold for that element type. Thus, detections satisfying an "OR" lucrativeness thresholds will always satisfy the "AND" lucrativeness criterion. Therefore, the "AND" lucrativeness effect is an incremental add-on to the unit POTA implied by the "OR" lucrativeness criteria. In TADER, a unit POTA is the probability that a scanned unit will be classified as lucrative with respect to either the "OR" lucrativeness criteria or the "AND" lucrativeness criterion.

GENERAL CASE

'OR' TARGET LUCRATIVENESS FOR A UNIT TYPE (NONCOUNTERFIRE)

- DETECTIONS UNDER THE 'OR' LUCRATIVENESS CRITERION FROM A NON-COUNTERFIRE SENSOR M OF SYSTEM S SCANNING A UNIT IN GRID SQUARE G ARE CLASSIFIED AS LUCRATIVE (WITH RESPECT TO THE UNIT) ONLY IF THE DETECTIONS ARE LUCRATIVE WITH RESPECT TO AT LEAST ONE TARGET ELEMENT TYPE

- FOR EACH UNIT/TGT ELT TYPE/SENSOR/GRID SQUARE, DEFINE

PMIN(I,J,M,S,G) = PROBABILITY THAT DETECTIONS OF ELT TYPE J IN UNIT I AND GRID SQUARE G BY SENSOR M OF SYSTEM S ARE <u>NOT</u> CLASSIFIED LUCRATIVE

= PROBABILITY <u>NOT</u> ENOUGH, I.E., LESS THAN THRES(I,J,K)xPTGT(I,J,K), OF ELT TYPE J ARE DETECTED TO QUALIFY AS LUCRATIVE

$$= \sum_{i=0}^{N} P(I,J,M,S,G,i)$$

Where N = NEAREST INTEGER LESS THAN THRES(I,J,K)xPTGT(I,J,K), AND

P(I,J,M,S,G,i) = OPERATIONAL PROBABILITY OF SENSOR M DETECTING EXACTLY i TARGET ELEMENTS OF TYPE J IN UNIT I AND GRID SQUARE G

A29

GENERAL CASE - "OR" TARGET LUCRATIVENESS FOR A UNIT TYPE (NONCOUNTERFIRE)

In TADER, combined detections of all element types in a unit by a noncounterfire system are defined as lucrative with respect to the "OR" lucrativeness criteria only if combined detections of at least one single element type are lucrative with respect to that element type, i.e., if detected elements of some type in the unit exceed the product of the "OR" lucrativeness threshold and the TOE for that element type.

The probability that at least one element type has detections exceeding the "OR" lucrativeness quantity is just (1. - the probability that all element detections are less than the lucrativeness quantity). Therefore, it is mathematically preferable to work with the probability that combined detections of an element type are <u>not</u> lucrative with respect to the "OR" lucrativeness quantity.

Define the term PMIN(I, J, M, S, G) as the probability that combined detections, by sensor M of system S, of element type J in unit I and grid square G are not lucrative with respect to that element type. This term is equivalent to the probability that fewer than N=(lucrativeness threshold)x(TOE) elements of type J are detected. By the properties of the binomial distribution, this is just the sum of the first N terms of the binomial distribution defined in Chart A25. Each PMIN value is computed for a single sensor and a single element type.

US ARMY

CONCEPTS ANALYSIS AGENCY

EXAMPLE CASE

'OR' TARGET LUCRATIVENESS FOR A UNIT IN A COVERED GRID SQUARE

- FOR UNIT I, ELT TYPE J=2 IN A GRID SQUARE G IN TGT ZONE IV, SENSOR M=1 OR 2, SYSTEM S=1,

  PMIN(I,J,M,S,G) = PROBABILITY LESS THAN .20 x 10 = 2 ELTS ARE DETECTED
  = .533 + .346 = .879

- FOR ELT TYPE J=3 IN ABOVE CASE

  PMIN(I,J,M,S,G) = PROBABILITY LESS THAN .20 x 20 = 4 ELTS ARE DETECTED
  = .284 + .369 + .228 + .089 = .970

- FOR ELT TYPES J = 1, 4, 5

  PMIN(I,J,M,S,G) = 1.0 BECAUSE POD(I,J,S,M,G) = 0 AND THEREFORE NO ELEMENTS OF THESE TYPES CAN BE DETECTED

- INTERM UNIT POTA ('OR' LUCRATIVENESS) = 1.-.879x.970=.147

A30

EXAMPLE CASE - "OR" TARGET LUCRATIVENESS FOR A UNIT IN A COVERED GRID SQUARE

PDET (J, L, S) = 0 for element types J = 1, 4, and 5 of the example case, so none of these element types can be detected. Therefore, there is zero probability of a lucrative detection of these element types. Hence, the associated PMIN (I, J, M, S, G) = 1.0 = probability of nonlucrative detection.

For element type J = 2 in the example case, the .20 lucrativeness threshold corresponds to .20x10 = 2 elements. Therefore, the related value of PMIN is just the summed first two terms of the associated binomial distribution, B(10, .061).

For element type J = 3 in the example case, the .20 lucrativeness threshold corresponds to .20x20 = 4 elements. Therefore, the related value of PMIN is just the summed first four terms of the associated binomial distribution B(20, .061).

The interim unit POTA under "OR" lucrativeness is then just 1 - the product, over element types, of the probabilities of nonlucrative detection, i.e., the PMIN values. This value is interim because sensor availability and survivability are not yet treated.

GENERAL CASE

'AND' TARGET LUCRATIVENESS FOR A UNIT

- FOR EACH UNIT/SENSOR/SYSTEM/GRID SQUARE DEFINE
  - ADD(I,M,S,G) = ADD-ON CONTRIBUTION TO UNIT DETECTION PROBABILITY FROM 'AND' LUCRATIVENESS CRITERION

    = 0 IF NO 'AND' LUCRATIVENESS IS SPECIFIED FOR BOTH ELT TYPES J=2,3

    $$= \prod_{J=1}^{5} A(J)$$

WHERE $$A(J) = \sum_{i=NA}^{NO-1} P(I,J,M,S,G,i) \ FOR\ J = 2,3$$

NO = 'OR' LUCRATIVENESS THRESHOLD = THRES(I,J,K) x PTGT(I,J,K)
NA = 'AND' LUCRATIVENESS THRESHOLD = ATHRES(I,J,K) x PTGT(I,J,K)
(WHERE K IS THE TARGET ZONE CONTAINING G) FOR J = 2,3
NA = 0 FOR J = 1,4,5

A31

GENERAL CASE - "AND" TARGET LUCRATIVENESS FOR A UNIT

For a single sensor observing a unit, the "AND" target lucrativeness is expressed as an add-on to the unit detection probability generated by the "OR" lucrativeness criteria. Although "AND" lucrativeness can be specified only for element types J = 2 and 3, an implicit "AND" lucrativeness threshold of zero is applied with all other element types (J = 1, 4, 5) in the following. For each element type J, compute:

A(J) = probability that detections of element type J are at least at the "AND" lucrativeness threshold but less than the "OR" lucrativeness threshold.

If both element types 2 and 3 have "AND" lucrativeness specified, then the product (over all J) of the A(J) is the add-on increment from the effect of the "AND" lucrativeness criteria. Otherwise, the add-on increment is zero.

Note that the "AND" lucrativeness threshold is just the product of the input "AND" lucrativeness fraction and the element TOE. An analogous statement applies to the "OR" lucrativeness threshold.

Because an "AND" lucrativeness is applied only against element types 2 and 3, it can only be meaningfully used with noncounterfire sensor systems.

US ARMY

CONCEPTS ANALYSIS AGENCY

EXAMPLE CASE
'AND' TARGET LUCRATIVENESS FOR A UNIT

- FOR J=2 NO=.20x10=2   AND NA=.10x10=1
- FOR J=3 NO=.20x20=4   AND NA=.10x20=2
- FOR SENSOR MISSION M=1 OR 2 SEARCHING A COVERED GRID SQUARE, G, IN TARGET ZONE IV
  - ADD(I,M,S,G) = ADD-ON TO UNIT DET PROB FROM 'AND' LUCRATIVENESS

$$= \sum_{i=1}^{1} P(I,2,M,S,G,i) \times \sum_{i=2}^{3} P(I,3,M,S,G,i)$$

$$= .346 \times (.228 + .089)$$

$$= .110$$

A32

EXAMPLE CASE - "AND" TARGET LUCRATIVENESS FOR A UNIT

For element type J = 2 the input lucrativeness fractions are .20 and .10 for the "OR" and "AND" conditions, respectively. The element TOE = 10, so the corresponding "OR" lucrativeness threshold is .20x10 = 2 while the "AND" lucrativeness threshold is .10x10 = 1. Therefore, the "AND" factor for J = 2 is just the probability that detections are at least 1 and less than 2, i.e., P(I,2,M,S,G,1). In a similar fashion, the "AND" factor for J = 3 is just the probability of at least .10x20 = 2 detections and less than .20x20 = 4 detections. Because inherent detection probability is zero for all other element types, the "AND" factor is 1.00 for each J = 1, 4 or 5. The product of all "AND" factors is then the add-on to the unit detection probability reflected in the "OR" lucrativeness criteria.

(NOT USED)

Section IX. NONCOUNTERFIRE SENSOR POTA CONSIDERATIONS

GENERAL CASE - SINGLE NONCOUNTERFIRE SENSOR POTA IN A GRID SQUARE

- FOR EACH UNIT I IN GRID SQUARE G, AND FOR EACH SENSOR M OF NONCOUNTERFIRE SYSTEM S DEFINE THE SINGLE-SENSOR POTA IN G AS:

  - POTM(I,M,S,G) = (SENSOR AVAIL PROB)x('OR'CONTRIB + 'AND' CONTRIB)

    = (PA(S)x(PROB NOT ENOUGH DET OF SOME ELT TYPE + ADD(I,M,S,G))

    $$= PA(S) \times (1. - \prod_{j=1}^{5} PMIN(I,J,M,S,G) + ADD(I,M,S,G))$$

  WHERE

  PA(S) = PROBABILITY SENSOR M IS AVAILABLE AND SURVIVES

  = FA(S) x FS(S)

A33

GENERAL CASE - SINGLE NONCOUNTERFIRE SENSOR POTA IN A GRID SQUARE

In TADER, a POTA for a unit is defined as the probability of that unit being detected as lucrative. The single-sensor POTA for a unit I in a grid square, G, in target zone K, scanned by sensor M of system S, denoted by POTM(I, M, S, G), is defined as the probability that sensor M detects unit I as lucrative with respect to either "OR" or "AND" criteria. By the laws of probability, POTM(I, M, S, G) is equal to the sum of the "OR" POTA (under only "OR" criteria) and the "AND" POTA (under only "AND" criteria). The "AND" POTA calculation is explained on the previous chart. The "OR" POTA is equal to PA x (1-PN) where PN is the probability that unit I detections by sensor M are not lucrative with respect to each and every element type, and PA is the sensor availability. The assumed independence of detections of different element types implies that PN can be expressed as the product of the nonlucrativeness probabilities for all the individual element types, i.e., of the PMIN(I, J, M, S, G) defined in Chart A29. The single-system POTA consists, as will be shown, of the combined effect, of the single-sensor POTAs.

CONCEPTS ANALYSIS AGENCY

EXAMPLE CASE - SINGLE NONCOUNTERFIRE SENSOR POTA IN A GRID SQUARE

- FOR A SLAR MISSION M VS. THE EXAMPLE UNIT IN A GRID SQUARE IN TARGET ZONE IV

$$\begin{aligned} POTM(I,M,S,G) &= .90 \times .99 \times (1. - (.879 \times .970) + .110) \\ &= .891 \times .257 \\ &= .229 \end{aligned}$$

A34

EXAMPLE CASE - SINGLE NONCOUNTERFIRE SENSOR POTA IN A GRID SQUARE

In a grid square, G, covered by a SLAR mission M, we have, from Chart A30, that:

$$PMIN(I,2,M,S,G) = .879$$
$$PMIN(I,3,M,S,G) = .970$$

Since inherent detection probability = 0 for element types 1, 4, and 5 (Chart A14), we have PMIN(I,J,M,S,G) = 1.00 for J = 1, 4, and 5.

The product of the PMIN terms (.853) is the probability of no lucrative detection under "OR" conditions. Therefore, 1.-.853 = .147 is the probability of lucrative detection under "OR" conditions. From Chart A32, the add-on increment from "AND" lucrativeness conditions is .110. The sum (.257) is the single-sensor POTA, given sensor availability, from both types of lucrativeness conditions. This is adjusted for sensor availability/survivability by multiplication by FA(S)xFS(S) (= .891).

US ARMY

CONCEPTS ANALYSIS AGENCY

SINGLE NONCOUNTERFIRE SYSTEM UNIT POTA IN A GRID SQUARE

GENERAL CASE

- FOR A NONCOUNTERFIRE SYSTEM S WITH NM SENSORS VS. A TARGET UNIT IN GRID SQUARE G, DEFINE THE SINGLE-SYSTEM POTA IN G AS:

  POTS(I,S,G) = PROBABILITY UNIT I IN GRID SQUARE G IS DETECTED AS LUCRATIVE BY (AT LEAST ONE SENSOR OF) SYSTEM S

  $$= 1. - \prod_{M=1}^{NM} (1. - POTM(I,M,S,G))$$

EXAMPLE CASE

- FOR THE EXAMPLE SLAR WITH NM=2 MISSIONS VS. THE EXAMPLE UNIT IN A COVERED GRID SQUARE IN TARGET ZONE IV

  POT(I,S,G) = $1 - (1. - .229)^2$

  = 1. - .594

  = .406

  = PROBABILITY UNIT IS DETECTED AS LUCRATIVE BY (AT LEAST 1 MISSION) OF THE SLAR SYSTEM

  POT(I,S,G) = 0 IN A GRID SQUARE NOT COVERED BY SYSTEM S

A35

SINGLE NONCOUNTERFIRE SYSTEM UNIT POTA IN A GRID SQUARE

The single-system POTA in grid square G is defined as the combined probability of detection from all NM sensors of the system. By our assumption of statistical independence, this is just 1. - (probability that no sensor of the system detects the unit as lucrative). Thus, the system POTA is expressed in terms of single-sensor POTAs.

For the example case, NM = 2 missions and, since both missions have identical characteristics, POTM(I,1,S,G) = POTM(I,2,S,G) = .229 (from Chart A34). The system POTA is zero for any grid square outside the range of (all missions of) the SLAR.

CONCEPTS ANALYSIS AGENCY

OVERALL UNIT POTA IN A GRID SQUARE FROM NONCOUNTERFIRE SYSTEMS

- **GENERAL CASE**
  - FOR A SCENARIO WITH NN NONCOUNTERFIRE SYSTEMS VS. A TARGET UNIT I IN GRID SQUARE G, DEFINE THE OVERALL (ALL NONCOUNTERFIRE SYSTEMS) POTA IN G AS:
  - POT1(I,G) = PROBABILITY UNIT I IN GRID SQUARE G IS DETECTED AS LUCRATIVE BY AT LEAST ONE SYSTEM

$$= 1. - \prod_{S=1}^{NN} (1. - POTS(I,S,G))$$

- **EXAMPLE CASE**
  - IN A COVERED GRID SQUARE, G, OF TGT ZONE IV POT1(I,G) = POTS(I,S,G) = .406 (BECAUSE NN=1)
  - POT1(I,G) = 0 IN GRID SQUARES NOT COVERED

A36

OVERALL UNIT POTA IN A GRID SQUARE FROM NONCOUNTERFIRE SYSTEMS

The overall unit POTA in a grid square from noncounterfire systems is the probability that at least one system detects the unit as lucrative. In computing it, single-system POTAs are combined in the same way that single-sensor POTAs were combined to form a single-system POTA. In the example case, the overall unit POTA is equal to the single-system POTA because there is only one system in the scenario.

(NOT USED)

Section X. COUNTERFIRE SENSOR LUC AND POTA CONSIDERATIONS

GENERAL CASE

'OR' TARGET LUCRATIVENESS FOR A UNIT TYPE (COUNTERFIRE)

- FIRINGS FROM ELT TYPES J=4,5 ARE SEARCHED FOR BY COUNTERFIRE SYSTEMS
- FOR EACH UNIT/ELT TYPE/COUNTERFIRE SENSOR/GRID SQUARE, DEFINE

PMIN(I,J,M,S,G) = PROBABILITY THAT DETECTIONS, BY SENSOR M OF SYSTEM S, OF OF A FIRING ELT TYPE J IN GRID SQUARE G ARE NOT LUCRATIVE

= 1. - (PROB LUCR DET WHEN UNIT IS FIRING)

$$= 1. - \sum_{i=N}^{NV} P(I,J,M,S,G,i)$$

WHERE

NV = NUMBER VOLLEYS FIRED BY (FIRING) UNIT I

N = ITHS(I,J) = LUCRATIVENESS THRESHOLD

P(I,J,M,S,G,i) = OP PROB OF SENSOR M DETECTING EXACTLY i (FIRED) VOLLEYS FROM ELT TYPE J

A37

GENERAL CASE - "OR" TARGET LUCRATIVENESS FOR A UNIT TYPE (COUNTERFIRE)

The treatment of "OR" target lucrativeness for an element type in a target unit scanned by a counterfire system is similar to that for noncounterfire systems. However, a counterfire detection can occur only if a unit is firing. Therefore, the probability of a lucrative detection of an element type in a firing target unit is expressed as the probability of a lucrative detection given that the unit is firing. The latter is based on binomially distributed detections exceeding the input lucrativeness threshold (expressed in terms of minimum number of volleys required). It is preferable to work with nonlucrativeness probabilities rather than lucrativeness probabilities. Therefore, PMIN, the single sensor probability of nonlucrativeness, is computed as (1 - probability of a lucrative detection).

GENERAL CASE - SINGLE COUNTERFIRE SYSTEM POTA VS A FIRING ELT TYPE IN A GRID SQUARE

- FOR A COUNTERFIRE SYSTEM WITH NM SENSORS VS ALL ELTS OF TYPE J (= 4 OR 5) IN A FIRING TARGET UNIT IN GRID SQUARE G, DEFINE THE SINGLE-SYSTEM POTA VS ELT TYPE J IN G AS:
  - POTZ (I,J,S,G) = PROBABILITY A LUCRATIVE NUMBER OF FIRING ELT TYPE J IN UNIT I IN GRID SQUARE G IS DETECTED BY SYSTEM S

    = 1 - PD

  WHERE

$$PD = \prod_{M=1}^{NM} PMIN(I,J,M,S,G)$$

A38

GENERAL CASE - SINGLE COUNTERFIRE SYSTEM POTA VS A FIRING ELT TYPE IN A GRID SQUARE

The single-system POTA for a counterfire system against firing element type J in grid square G, is just 1 - PD, where PD is the probability that no sensor of the system has a lucrative detection of element type J. Equivalently, PD is the product, over all sensors of the system, of the nonlucrativeness probabilities for each sensor against element type J. The single-system POTA can be interpreted as the probability that the system detects a lucrative number of element type J given that is firing.

OVERALL POTA FROM COUNTERFIRE SYSTEMS VS AN ELT TYPE IN A UNIT IN A GRID SQUARE

- FOR A SCENARIO WITH NC COUNTERFIRE SYSTEMS VS AN ELT TYPE J IN A TARGET UNIT IN GRID SQUARE G, DEFINE THE OVERALL COUNTERFIRE POTA (FOR ALL COUNTERFIRE SYSTEMS) VS ELT TYPE J AS:

POTE (I, J, G) = PROBABILITY A LUCRATIVE NUMBER OF ELT TYPE J (=4 OR 5) IS DETECTED BY AT LEAST ONE COUNTERFIRE SYSTEM,

$$= \mathrm{PFIR}(I, J, K) \times \left(1. - \prod_{S=1}^{NC} \left(1 - \mathrm{POTZ}(I, J, S, G)\right)\right)$$

WHERE PFIR (I, J, K) = PROB UNIT I IS FIRING ELT TYPE J IN ZONE K CONTAINING GRID SQUARE G

A39

OVERALL POTA FROM COUNTERFIRE SYSTEMS VS AN ELT TYPE IN A UNIT IN A GRID SQUARE

The overall POTA versus element type J (= 4 or 5) from counterfire systems is the product of the probability that element type J is firing and the probability that at least one counterfire system detects a lucrative number of element type J, given that is firing. The firing probability is input. The POTA is calculated in terms of the probability that all counterfire systems have nonlucrative detections of element type J, given element type J is firing.

(NOT USED)

Section XI. OVERALL UNIT POTA DETERMINATION

US ARMY

CONCEPTS ANALYSIS AGENCY

OVERALL UNIT POTA FROM COUNTERFIRE SYSTEMS

- FOR A SCENARIO WITH NC COUNTERFIRE SYSTEMS VS A TARGET UNIT I IN GRID SQUARE G, DEFINE THE OVERALL (ALL COUNTERFIRE SYSTEMS) POTA IN G AS:

POT2 (I,G) = PROBABILITY UNIT I IN GRID SQUARE G IS DETECTED AS LUCRATIVE BY AT LEAST ONE COUNTERFIRE SYSTEM,

$$= 1. - \prod_{j=4}^{5} (1. - \mathrm{POTE}(I, J, G))$$

A40

OVERALL UNIT POTA FROM COUNTERFIRE SYSTEMS

The overall unit POTA in a grid square from counterfire systems is the probability that at least one counterfire system detects a lucrative number of volleys from at least one firing element type. Since there are only two element types (4 and 5) whose firing is detected by counterfire, the overall unit POTA is also 1 - (probability neither element type 4 or 5 is detected as firing by any system), which can be expressed in terms of the complements of the overall POTA vs. element type computed previously.

Since the example case has no counterfire sensors, the overall unit POTA from such sensor systems is zero.

OVERALL UNIT POTA FROM ALL SYSTEMS

- COMBINE THE OVERALL POTAS FROM NONCOUNTERFIRE SYSTEMS AND COUNTERFIRE SYSTEMS INTO

POTA (I, G) = PROBABILITY UNIT I IN GRID SQUARE G IS DETECTED AS LUCRATIVE

= 1. - (1. - POT1(I,G)) X (1. - POT2(I,G))

A41

OVERALL UNIT POTA FROM ALL SYSTEMS

The overall POTAs for *noncounterfire* and *counterfire* systems *must* be *combined* to *get* the final overall unit POTA. The final unit POTA is calculated as 1 - PC, where PC is the probability no system detects unit I as lucrative. Using statistical independence, the latter can be expressed as the product of two terms, calculated for each grid square G.

(1) The probability that no *noncounterfire* system detects unit I as lucrative.

(2) The probability that no counterfire system detects unit I as lucrative.

Since the final unit POTA above is calculated for a unit located in a specific grid square, it *remains* to *compute* a final unit POTA *for an* entire target zone.

US ARMY

CONCEPTS ANALYSIS AGENCY

OVERALL UNIT POTA IN TARGET ZONE

- POTA(I,K) = PROBABILITY UNIT I IN TARGET ZONE K IS DETECTED AS LUCRATIVE BY AT LEAST ONE SYSTEM

  = AVERAGE OF POTA(I,G) OVER ALL GRID SQUARES, G, IN TARGET ZONE K

- EXAMPLE CASE

  - ONLY 67% OF TARGET ZONE IV IS COVERED BY THE SLAR (CHART A12)

  - POTA(I,G) = .406 IN THE COVERED PART OF ZONE IV (CHART A35)
    POTA(I,G) = .000 ELSEWHERE IN ZONE IV
    POTA(I,4) = .67 x .406 + .33 x .00 = .272

A42

OVERALL UNIT POTA IN TARGET ZONE

The (overall) unit POTA for unit I in a target zone K is the probability that a unit I, randomly located in target zone K, is detected as lucrative by at least one system of the scenario. It is computed as the arithmetic average of the overall unit POTAs computed in each grid square of the target zone. In the example case in target zone IV, since all covered squares of the zone have the same unit POTA (.406) and since only 67 percent of zone IV is covered by the SLAR, the overall unit POTA in the zone is just .67 x .406 = .272.

(NOT USED)

Section XII. TADER SUMMARIES

TADER INPUT/OUTPUT SUMMARY

INPUTS

- BATTLEFIELD SECTOR SCANNED (TARGET ZONES)
- SENSORS (TYPES, NUMBER, PLACEMENT, CHARACTERISTICS, OPERATING CONDITIONS)
- TARGETS (UNITS, ELEMENTS (TOE), ACTIVITIES, ENVIRONMENTS, ARTY/MORTAR FIRE DATA)
- THRESHOLDS OF TARGET LUCRATIVENESS ('OR, 'AND')

OUTPUT - FOR EACH COMBINATION OF TARGET UNIT AND TARGET ZONE

- AVERAGE PROBABILITY THAT THE UNIT IN (A RANDOM LOCATION IN) THAT TARGET ZONE IS DETECTED AS LUCRATIVE
- RESTRICTION - APPLICABILITY OF OUTPUT POTAS IS LIMITED TO THE SPECIFIC INPUT CONDITIONS USED TO COMPUTE THEM

A43

TADER INPUT/OUTPUT SUMMARY

The TADER methodology inputs are for specific scenarios, each containing a group of sensor systems and specific type targets. Each sensor system consists of specifically emplaced sensors scanning designated zones within the battlefield sector. Average (over activities and environments) target units of specified composition are located randomly in the target zone. Basic data on single sensor versus single target element detection is input, along with operational degradation factors for environmental and battle conditions. Based on user-specified "OR" and "AND" thresholds of desired target lucrativeness, TADER calculates, for each combination of target unit and target zone, the average probability that the unit is detected as a lucrative target by the full array of scenario sensor systems scanning the battlefield sector. Applicability of a computed POTA value is always restricted to the specific scenario (input) conditions used to generate it.

TADER METHODOLOGY SUMMARY

TADER

- TREATS DETECTIONS AS STATISTICALLY INDEPENDENT
- TREATS ONLY EXPECTED VALUE INPUTS AND PROCESSES
- USES COMPUTERIZED GRAPHIC SEARCH TO ASSESS SENSOR SYSTEM COVERAGE IN A TARGET ZONE
- USES BINOMIAL PROBABILITY DISTRIBUTIONS TO BUILD A LUCRATIVE DETECTION PROBABILITY FOR EACH SYSTEM VS EACH UNIT FROM BASIC DATA FOR SINGLE SENSORS VS SINGLE ELEMENTS
- COMBINES UNIT DETECTION PROBABILITIES FROM SINGLE SYSTEMS INTO A UNIT DETECTION PROBABILITY FROM ALL SYSTEMS (A UNIT POTA)
- COMPUTES A UNIT POTA AT MANY POINT LOCATIONS IN A TARGET ZONE AND AVERAGES THEM TO PRODUCE A UNIT POTA FOR THE ZONE

A44

TADER METHODOLOGY SUMMARY

TADER treats probabilities of detection as statistically independent of each other. All processes and inputs are based on expected values over a fixed timeframe. Sensor coverage patterns are rigid in form, i.e., "cookie-cutter" type. Probability of sensor coverage in a target zone is based on a computerized graphic search determination of pattern and target overlaps. Once computed, probability of target coverage is combined with the degraded probability of detection given coverage. The model constructs unit detection probabilities over grid squares in each target zone in the following sequential manner:

(1) Operational detection probabilities are computed for a single sensor versus a single target element.

(2) The single-sensor/single-element operational detection probability is taken as the single event probability of a binomial distribution for the number of detections by the sensor scanning a specific target unit. The single sensor probability of lucrative detection is then computed, based on the specified "OR" and "AND" lucrativeness thresholds.

(3) The single sensor probabilities of lucrative detection for each grid square are combined into an overall (all systems) probability of lucrative detection of a unit in the grid square.

TADER computes the overall unit detection probability at many grid squares (point locations) within a target zone and averages the values to determine a POTA for the zone.

APPENDIX B

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GLOSSARY

ABBREVIATIONS, ACRONYMS, SHORT TERMS, AND SYMBOLS

A/E	activity/environment
A(J)	probability that detection of element type j are at least at the "AND" lucrativeness threshold but less than the level of the "OR" lucrativeness threshold
ACFT	aircraft
ACT/ENV	activity/environment
ADD(I,M,S,G)	add-on to unit I detection probability from "AND" lucrativeness (by sensor M of system S searching grid square G)
ATHRES(I,J,K)	minimum fraction of the TOE for element types J = 2 and 3 in unit I that must both be detected in target zone K to classify the detection as lucrative with respect to "AND" lucrativeness
CAA	US Army Concepts Analysis Agency
COMBIN	combination
CP	command post
DEG(S,L)	environment/crew degradation factor for a sensor of system S searching sensor zone L
DET	detection
ELT	element
EMPL	emplaced
FA(S)	probability a sensor of system S is available (availability factor)
FAALS	forward area acoustic locating system
FACT(I,J,K,A/E)	fraction of target elements of type J in unit I and target zone K which are in activity/environment A/E
FC(J,L,S,A/E)	fraction of inherent detection capability applicable to a single sensor of system S vs. a single element of type J in sensor zone L and activity/environment A/E

FEBA	forward edge of the battle area
FLOT	forward line of own troops
FS(S)	probability a sensor of system S survives (survivability factor)
G	subscript designating grid square
HUMINT	human intelligence
I	subscript designating target unit
IPB	intelligence preparation of the battlefield
IRPS(I,J)	number of rounds fired per volley by a firing element J = 4 or 5 in Unit I
ISAL(I,J,K)	number of volleys fired by a firer element of type J in target zone K during search period (J = 4 or 5)
ITHS(I,J)	minimum number of volleys of fired element type J rounds (J=4 or 5) in unit I that must be detected by a counterfire system to classify the detection as lucrative with respect to element type J
J	subscript designating element type
K	subscript designating target zone
L	subscript designating sensor zone
M	subscript designating an individual sensor in a sensor system
NUFAM III	Nuclear Fire Planning and Assessment Model III
NUREM	Nuclear Requirements Methodology
NUREQ-84	Theater Nuclear Force Requirement - 1984 Study
NUREQ-92	Theater Nuclear Force Requirement - 1992 Study
OP	operational
P(I,J,S,M,G,N)	operational probability of sensor M of system S detecting exactly N target elements in unit I in grid square G
PA(S)	probability a sensor of system S is available and survives

PCPF(S)	degree, on average, to which crew performance may be expected to degrade PDET
PD(J,K,L,S,A/E)	probability of operational detection, given coverage, by a single sensor of system S scanning a single target element of type J in activity/environment A/E in sensor zone L and target zone K
PDET(J,L,S)	inherent probability that a single mission (or sensor) of sensor system S detects a single target element of type J under ideal conditions in sensor zone L
PFIR(I,J,M)	fraction of all deployed units of type I in target zone K which are firing, from elements of type J(= 4 or 5) during the search period
PLOS(L,S)	probability of clear line of sight from a sensor of system S to a target element in sensor zone L
PMIN(I,J,M,S,G)	probability that detections of element type J, in unit I and grid square G, by sensor M of system S are not classified lucrative, i.e. probability not enough of element type J are detected to qualify as lucrative
POD(I,J,S,M,G)	same as PODT(I,J,K(G), L(G), S) if G is in the coverage region of sensor M, where L(G) = sensor zone containing G and K(G) = target zone containing G; = 0 if G is not in coverage region of M
PODR(I,J,K,L,S)	For a counterfire system S, this is the average operational probability of detection by a single available and surviving sensor (of system S) of a single round, fired by element type J in unit I, within sensor coverage in sensor zone L and target zone K
PODT(I,J,K,L,S)	average operational probability of detection by a single available sensor (in system S) of a single elt (of type J in unit I) within that sensor's range (coverage) and located in sensor zone L and target zone K
	for a counterfire system S, this is the average probability of detection by a single sensor (of system S) of (at least one round of) a volley fired by element type J within coverage range in sensor zone L and target zone K
POK	percent of knowledge

POTA	probability of operational target acquisition
POTA(I,G)	probability at least one system detects unit I as lucrative in grid square G
POTA(I,K)	the unit POTA for unit I in target zone K, i.e., the probability that unit I, randomly located in target zone K, is detected as lucrative by at least one system
POTAR	probability of operational target acquisition routine
POTM(I,M,S,G)	noncounterfire single-system POTA for sensor M of system S versus unit I in grid square G
POTS(I,S,G)	probability unit I in grid square G is detected as lucrative by (at least one sensor of) noncounterfire system S
POT1(I,G)	probability unit I in grid square G is detected as lucrative by at least one noncounterfire system
POT2(I,J,G)	probability that a lucrative number of element type J = 4 or 5 in unit I and grid square G is detected by at least one counterfire system
POTZ(I,J,S,G)	probability a lucrative number of firing element type J in unit I in grid square G is detected as lucrative by counterfire system S
PROB	probability
PSMO(S)	degree, on average, to which smoke may be expected to degrade PDET
PTGT(I,G,K)	number of target elements of type J in unit I and target zone K
PWEA(S)	degree, on average, to which weather may be expected to degrade PDET
PWIND(S)	degree, on average, to which wind may be expected to degrade PDET
QA	quality assurance
REMBASS	remotely monitored battlefield surveillance system
RPV	remotely piloted vehicle
S	subscript designating sensor system

SIGINT	signal intelligence
SLAR	side-looking airborne radar
STANO	surveillance, target acquisition, and night observation
TADER	Target Detection Routine
TAS	Target Acquisition Study
TAS II	Target Acquisition Study II
TAS III	Target Acquisition Study III
TGT	target
THRES(I,J,K)	minimum fraction of TOE for element type J in unit I that must be detected in target zone K to classify the detection as lucrative with respect to "OR" lucrativeness
TOE	table of organization and equipment
TNF	tactical nuclear force

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